MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA

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THE MICA DEPOSITS OF INDIA, *by* THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Officiating Superintendent, Geological Survey of India.*

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I.—INTRODUCTION.

The primary object of this paper is to describe the Indian occurrences of mica commercially valuable. As this last expression implies mica-crystals of a certain size and without the flaws usually and easily produced by earth-movements, the geologist will readily see that the ground to be considered must of necessity be very limited in extent. Such an area must be one from which the sedimentary mantle has been completely removed and on which denudation has been sufficiently thorough to bring the deep-seated plutonic rocks to the surface, an area, too, which has escaped all tectonic movements since the formation of its pegmatites; for mica, being the most delicate, is amongst the first of rock-constituents to suffer deformation from crust disturbances. Occurrences combining these characters are necessarily few and comparatively restricted in extent, and for such reasons the available mica supplies of the world are strictly limited—a fact of the highest concern to the country which happens to possess an area so large and geologically so suitable that it is likely to have the means of controlling, if not of actually monopolising, the

mica supplies of the world. The importance of this circumstance is further accentuated by the fact that the remarkable physical properties, which have secured for mica its extensive use in the Arts, are not possessed by any other mineral, and are not, and not likely to be, imitated by any artificial substance. The mica-miner should not be surprised, therefore, if the Government show an inclination to temper the encouragement given to his industry with restrictions intended to discourage his wasteful methods of mining and the tendency which he has shown, not unnaturally, to secure immediate returns by wantonly excavating shallow workings over large areas. It is hoped, nevertheless, that the criticisms which accompany the advice given in a subsequent chapter will be found to benefit the mica-miner as much as the holder of mineral rights, the interests of both being necessarily interdependent.

As a further object, this paper is intended to convey to the mica-miner a brief resumé of the nature and history of the mineral in which he is so largely interested; and, finally, it is made the means of recording, for the information of mineralogists interested only in scientific questions, the new facts of value concerning the natural history of mica which the detailed study of its Indian occurrences has revealed to the writer and his colleagues.

The use of simple names expressing the very prominent lustrous character of minerals like the micas, talc and selenite has made it difficult to determine the exact species referred to in any but the most recent scientific literature.[1] The highly perfect basal cleavage, which permits both mica and talc to be split into thin laminæ, has helped to maintain the confusion which exists in the popular mind between these two species, but which is now becoming removed gradually by the more extended use of the mineral mica in the Arts and its commoner appearance as an article of ordinary trade.

[1] Selenite, σεληνιτης (Dioscorides, *Cir. A.D. 50*), now used for the crystallized hydrous sulphate of lime or gypsum, was the equivalent of Pliny's *lapis specularis*, which, however, from its use (to produce a whiteness on the "Circus Maximus") was probably mica.

The word *mica* is referred to the Latin *mico*, I shine, and in some form or other its perfect reflective and sparkling properties are expressed by its names in most languages.

Mineralogists are accustomed to correct—not without a touch of self-conscious superiority—the common use of the word *talc* for the minerals now grouped under the generic term *mica*. But as a matter of priority the common usage has probably superior claims, as the word talc appears to be much older and was applied to the large sheets of mica used for window-panes. According to Lane the word طلق (*talq*) is an Arabicized form of تلك (*talak*) ; but the original meaning of the word does not appear to be known. The prominent sparkling character of the mineral is expressed in Arabic by the name كوكب ال أض (*kaukabu-l-az*), "the star of the earth," and references to its use as window-panes show the true nature of the mineral.[1] The use of the term mica for the minerals described in this note is now, however, so well established that it would be futile to attempt the reinstatement of the name talc, even if there was any advantage in the reform. The word talc is reserved by the mineralogist for the hydrous silicate of magnesia which is well known in one of its forms as steatite and French chalk.

The romance languages follow the Latin ; but in German we have *Glimmer*, whilst the common name in Hindustani *abrak* (ابرق) from *abr*, a cloud, or *abru*, heavens, goes a step further, and connects its lustrous character with its supposed celestial origin. The Hindu classical writers imagined mica to be a sort of petrified lightning-flash, hence the use of *vajra* (*bazar*), thunderbolt, as one of its names. In ancient times, or *Sat Yoga*, it is supposed that in order to kill the enemy of the gods, *Baratur* (*Vitra*), Indra lifted his thunderbolt *vajra*, and a flash of lightning spread throughout the length and breadth of the sky, whilst the sparks which fell on the mountains were preserved in the form of mica.[2] Other names, like *gagana* (sky) and

[1] The writer is indebted to Col. G. S. A. Ranking, I.M.S., for this information.

[2] "Kabi-kal Padrama," a Sanskrit work quoted by Raja Sir Radha Kanto Deo in his Sanskrit Dictionary.

meghalála [from *megha* cloud, and *lála*, red (sparks)], are derived from a similar idea.[1]

In Tibetan a similar name for mica is used—*nam-do*, sky-stone.[2]

As in the case of gems,[3] ancient Hindu writers distinguished four qualities of mica under the names of their four great divisions of caste :—The *Brahman* was white and colourless ; the *Kshatriya*, red-tinted ; the *Vaisya*, yellow, and the *Súdra*, black. Four varieties were also distinguished by special names and were supposed to be possessed of wonderful medicinal properties—the *Pináka* variety when thrown into fire splits into laminæ, and if swallowed accidentally produces leprosy; the *Dadura* when thrown into fire emits a noise like a croaking frog, and its internal use produces death; the *Nága* variety hisses like a snake when heated, and would give rise to fistula if swallowed; whilst the *Vajra* is not affected by fire, and is the best of all, removing the infirmities of age and preventing untimely death. Apparently the main use of mica in ancient times in India was for medicinal purposes, and the legend of its origin served as a good base on which to build accounts of its magical properties—properties which produced the most calamitous results when the mineral was used unrefined, and healing properties for the most deadly diseases when prepared by the long and tedious processes detailed by the physician, whose chief idea seems to have been to mystify the uninitiated by processes too complicated and long for imitation by the amateur, a relic of which we have in the language and characters of the modern prescription.[4]

[1] The writer is indebted to Raja Sir Sourindro Mohan Tagore, Kt., C.I.E., Lala Kishen Singh of the Geological Survey and Babu Brajendra Lal Mitra, M.A., a former pupil in the Presidency College, Calcutta, for numerous extracts from the Sanskrit classics with reference to mica. Here and in the pages which follow many of these references are made use of without special acknowledgment, as most of them have been obtained by all three friends, showing a fairly complete research, for which the writer is much indebted.

[2] Waddell, "Among the Himalayas," 1899, 408.

[3] See Geol. Surv. Ind. Manual on Corundum (1898), p. 58.

[4] A detailed account of the laborious methods said to be necessary in preparing mica for medicinal purposes is given in Sir Sourindro Mohan Tagore's "Abhra" (Calcutta, 1899) and in Dr. U. C. Dutt's "Materia Medica." The former work contains a list of 224 medicines in which mica is used, with the diseases in which the medicines are employed.

The establishment all over India of Government dispensaries in charge of qualified apothecaries has almost put an end to the absurd use of mica as a drug; and the consumption of the mineral within the country is practically confined to purposes of ornament which are referred to on a later page.

II.—MINERALOGICAL AND CHEMICAL CHARACTERS.

The minerals of the mica group, though differing considerably in chemical composition and though exhibiting variations in certain physical properties, possess one common striking characteristic—a highly perfect, basal cleavage, by which the crystals can be split into the thinnest films.

The acute bisectrix of the optic axes being very nearly at right angles to the basal plane of the mica-crystal, these lamellæ, so easily obtained, form a convenient means for classifying the different varieties of mica according to their optical properties.[1] Two groups are distinguished according to whether the optic axial plane is approximately parallel, or approximately at right angles, to the equivalent of the plane of symmetry. These are as follows :—

GROUP I.	GROUP II.
(Optic axial plane perpendicular to the plane of symmetry.)[2]	*(Optic axial plane parallel to the plane of symmetry.)*[2]
Muscovite.	Phlogopite.
Lepidolite.	Lepidomelane.
Paragonite.	Zinnwaldite.
Margarite.	Biotite (Meroxene variety.)[3]
Anomite (a variety of Biotite.)[3]	

[1] As stated in the introduction, this paper is primarily intended for the use of those in India interested in the mica industry. The writer's acquaintance with most of these leads him to suppose that an account of the properties of the minerals, as worked out by mineralogists, will not be unappreciated, and although many unfamiliar terms are, for the sake of precision, necessarily employed without explanation, they represent properties concerning the nature of which an empirical knowledge at least is easily acquired. For the satisfaction of the trained mineralogist it is necessary to state that, whilst many of the facts recorded in this chapter

The crystal-outlines are not always visible in mica, more generally they are not exhibited in ordinary specimens. In such cases the direction of the so-called plane of symmetry can be determined by producing a *percussion-figure.* For this purpose a thin mica plate is placed on a sheet of cardboard, or similar firm plane surface, and is then struck a sharp blow with a blunt needle point. A six-rayed star is produced in this way, the cracks intersecting at the centre of percussion at angles of 60° *approximately.*[1]

The ray which lies nearly parallel to the clinopinacoidal plane (that is, to the plane of symmetry)[2] is spoken of as the characteristic, or leading, ray, and this, in the first group of micas (muscovite and its fellows), lies at right angles to plane of the optic axes, whilst in the second group of micas (biotite, phlogopite, etc.) it lies nearly parallel

are mere restatements of facts known concerning the mica group, the statements are not made without special verification on micas of Indian origin, and some of them represent facts hitherto unrecorded.

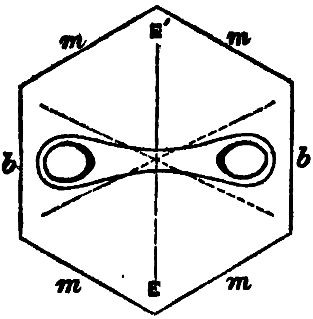
[2] The plane of symmetry is referred to as if the micas were all monoclinic in their system of crystallization. Reasons are given below for considering muscovite to be truly monoclinic; but in some other micas the asymmetry of the etch-figures and the slight divergence of the optic-axial plane from what appears to be the symmetral plane of the geometrical crystal indicate triclinic forms. It is possible that the apparently higher type of symmetry is produced by a twinning of a triclinic form on a scale too minute for recognition by tests less precise than that afforded by etch-figures. This introduces theoretical questions beyond the scope of this paper; it is sufficient to recognise the fact that, as in the case of the felspars, there is a sufficient homology of crystal-habit recognisable throughout both monoclinic and triclinic types to permit identification of corresponding forms. The expression "plane of symmetry" may thus be not quite correct in the case of some micas, whilst "parallel to" and "perpendicular to" this plane mean *approximately* parallel, or perpendicular, to the plane which occupies the position of the symmetral plane in a monoclinic mineral.

[3] Tschermak divides biotite into two varieties, *meroxene*, which includes all ordinary forms met with in crystalline rocks, and *anomite* (from ἄνομος, contrary to law) a rarer variety having its optic axial plane at right angles to the usual direction.

[1] It will be seen below that the common assumption of the mineralogical text-book is not quite correct in referring the angles of the percussion-figure to 60°.

[2] See foot-note 2, p. 16.

to that plane. These two statements are represented diagrammatically by figs. 1 and 2.



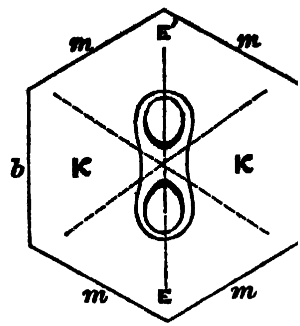


FIG. 1. FIG. 2.

m, Traces of the prism faces.
b, Traces of the clinopinacoid or its equivalent.
EE', Leading line of the percussion-figure.

By subjecting a sheet of mica to a gradually increasing pressure with a blunt punch, another six-rayed figure, the so-called *pressure-figure*, is produced with rays approximately bisecting the angles of the percussion-figure (see plates VI and VII). Mica-crystals are often found in which these pressure-figures have been produced by natural earth pressures when embedded in the rocks (see plate VI), and the crystals often split along these lines, forming pseudo-crystal faces, which are inclined at about 67° to the basal cleavage-planes. The occurrence of numerous fissures parallel to the pressure-figure lines is the cause of the fibrous mica so frequently found in these so-called gliding planes. These fibres are often found in muscovite aligned most perfectly at right angles to the leading ray of the percussion-figure.

Allusion has already been made in a foot-note to the fact that the rays of the percussion-figure do not (as was generally supposed on account of the statements of Max Bauer) intersect one another at angles of 60°. Dr. T. L. Walker, who first called attention to this fact, has measured the angles of the percussion-figures in a large number of micas from various parts of the world, and has found that

the angle indicated by the letter κ in figure 2, varies from about 51° in some muscovites to 64° in some phlogopites, whilst the lithia-micas and biotite approximate more nearly to 60°.[1]

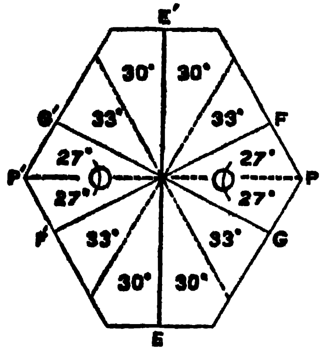


FIG. 3. *Diagram showing the average relations of the pressure-figure, percussion-figure and optic-axial plane in Indian muscovites.*

The writer has examined the percussion and pressure figures in some 30 Indian muscovites and has found the relations graphically expressed in figure 3 and on plates VI and VII to represent to the nearest degree the average of some 200 determinations. The principal results may be summarised as follows:—

(1) The principal ray of the percussion-figure EE′ lies in the plane of symmetry and at right angles to the optic-axial plane.

(2) The principal ray is cut perpendicularly by the ray PP′ of the pressure-figure, which lies in the optic-axial plane.

(3) The angle κ between the rays FF′ and GG′ averages 53° 55′ (nearly 54°).

(4) The remaining angles of the percussion-figure are, to the nearest degree, each 63°.

(5) The rays of the pressure-figure intersect one another as nearly as can be measured at angles of 60°.

[1] T. L. Walker, "The crystal symmetry of the minerals of the mica group." *Amer. Journ. Sci.*, Vol. VII, 1899, p. 199; "Percussion-figures on micas." *Rec. Geol. Surv. Ind.*, Vol. XXX (1897), p. 250.

(6) The subordinate rays of the percussion-figure meet the subordinate rays of the pressure-figure at angles of 93° and 33°.

(7) The etch-figures produced by the action of hydrofluoric acid or by fused potash are bisected symmetrically by the principal ray EE′ of the percussion-figure.

The physical properties of a plate of muscovite are thus ranged symmetrically with regard to a single line, namely, the leading ray of the percussion-figure; and, as the optic-axial plane is, according to Tschermak, slightly inclined to the basal cleavage-plane, the mineral muscovite must be regarded as monoclinic in its crystallization. In many points muscovite is imitated by its chemically near relative, lepidolite; but the asymmetric character of the etch-figures in phlogopite and biotite, and the oblique disposition of their optic-axial planes with reference to the leading percussion rays, suggest that their crystal symmetry belongs to a lower grade.[1] But the micas frequently show twin-lamellæ parallel to the basal plane, and, as the general effect of twinning is an apparent increase of symmetry, it is just possible that the higher grade of symmetry exhibited by muscovite may be due to twinning on a scale too minute to be detected by our ordinary physical tests.

A very interesting occurrence of *natural pressure* and *percussion figures* was found by Dr. T. L. Walker at Gudladona in the Nellore district. The rays of both figures appeared to radiate from an inclusion in the mica, apparently an altered allanite; on examination it was found that the rays of the compound figure intersected one another as nearly as possible at angles of 30°, and that one of the rays occupied the correct position of the principal ray of the artificially produced percussion-figure. Regarding this compound twelve-rayed figure as the result of the symmetrical intersection of the percussion and pressure figures we have to meet the difficulty that the natural percussion-figure, unlike that produced by artificial means, is formed

[1] *Cf.* Walker, *loc. cit.*

by the intersection of rays at 60°. It occurred to the writer that possibly at a higher temperature, muscovite, like some other minerals, might present a higher grade of crystalline symmetry; in other words its percussion-figure might possibly be hexagonal instead of monoclinic in its symmetry at the temperature at which these natural figures were produced. To test this idea the writer produced percussion-figures on several muscovites heated to the temperature of melted lead (about 300°C.), and found that the angle κ was invariably larger when produced at a high temperature than the corresponding angle obtained on the same mica at ordinary temperatures. The following are the figures actually obtained as averages of several determinations on each sample of mica:—

Locality.	Angle κ of percussion-figure produced at	
	ordinary temperatures.	about 300° C.
Saidápuram, Nellore	55°	57° 30′
Inikúrti, Nellore	54°	57°
Útukúr, Nellore	53° 30′	56°
Koderma, Hazáribágh	53°	56°

In the commonest form of *twinning* the individuals are joined along their basal planes, and the vertical faces then show re-entrant angles as in fig. 4. Twinning of this type repeated on a very minute scale is probably the cause of some micas behaving as monoclinic crystals to

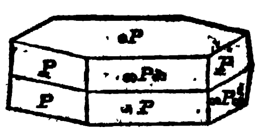


FIG. 4. *Muscovite crystal twinned parallel to the basal plane.*

optical tests, whilst their etch-figures indicate triclinic crystallization.

In other cases a well formed, six-sided crystal, apparently simple, may be found on examination in polarised light to be composed of two or more individuals, having an irregular junction-line, but with their lateral axes (determined by the position of the optic-axial plane) disposed at angles of about 60° to one another. Some fine examples of this form of twinning have been obtained near Kangayam in the Coimbatore district, Madras. One such is represented by fig. 5, which recalls the intergrowths sometimes found in apparently simple hexagonal crystals of quartz.

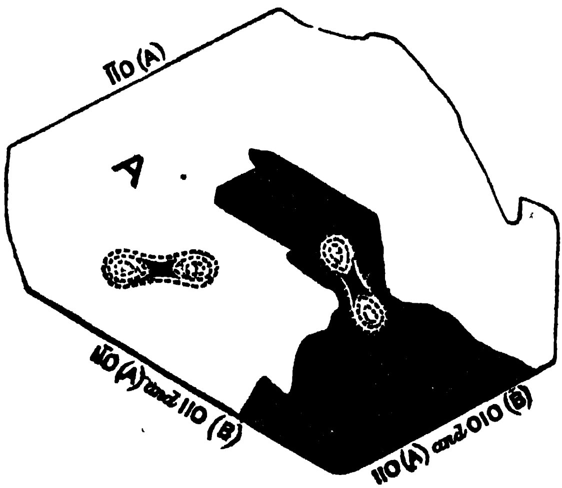


FIG. 5. *Six-sided crystal of muscovite formed by the intergrowth of two individuals, from near Kangayam, Coimbatore district, Madras.*

All micas are negative in the kind of *double refraction* which they exhibit, but the angle between the optic axes varies from 70° in muscovite to about 10° in phlogopite and still less in biotite; so that the character of the figure obtained by examining cleavage plates in convergent polarised light forms a ready means of distinguishing between the common members of groups I and II (p. 16).

Muscovite is practically devoid of *pleochroism*, whilst in biotite there is always a great contrast between the colour of rays vibrating parallel to, and that of the rays vibrating across, the basal cleavage

lines. The absorption of the rays vibrating parallel to the cleavage in biotite is always very great and is sometimes sufficient in the deeply coloured varieties to make the thin section of the mineral appear almost black.

The *colours* in ordinary light vary very greatly, but the ferro-magnesian micas are most deeply coloured and are often deep-brown, even in thin films. The characteristic colour of lepidolite is a delicate lilac, pink or grey (Pihrá, Hazáribágh district). Some of the muscovite raised in the Hazáribágh district is noted for its red tint which in thick sheets may be a deep ruby-colour. Amber-coloured, smoky brown and, in one locality, deep grass-green muscovite is obtained in the Nellore district of Madras. The colours and the character of the lustre are changed on hydrous alteration of the mica, or are modified by the presence of inclusions of other mineral matter. A peculiar pearly or silvery lustre, displayed by muscovite obtained near Bendi in the Hazáribágh district and a few other localities, is due to the removal of exceedingly thin films of decomposed mica from the cleavage surfaces. Numerous minute inclusions in phlogopite, like that from near Waltair, Madras Presidency, give the mineral a bronzy colour and semi-metallic lustre. The same mineral often exhibits the remarkable phenomenon of *asterism* from the same cause. The phlogopite from Waltair when interposed between the eye and a candle-flame or other small point of light, shows a six-rayed star, in which one pair of rays is specially pronounced and appears as a bright band of light always disposed at right angles to a prominent striation noticeable in the mineral, and at right angles also to the leading line of the percussion-figure (figs. 6 and 7). The less prominent rays of the ligh star cross the bright band at angles as nearly as can be measured of 60°. The pleochroism of this phlogopite is also quite distinct, showing a pink tinge for rays vibrating (nearly) at right angles to the striation, and a greenish tinge for rays vibrating (nearly) parallel to the striation. The optic-axial angle in this specimen is too narrow to permit a safe determination of the direction of the plane of the optic axes. The cause of asterism has been attributed to

Striated phlogopite from Waltair, Madras Presidency.

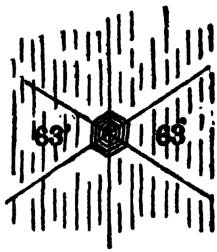


FIG. 6. *Percussion-figure with leading line parallel to the striation.*

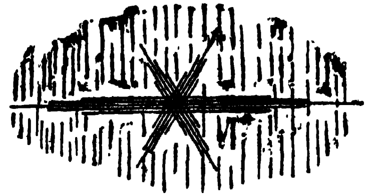


FIG. 7. *Asterism with prominent ray traversing the striation perpendicularly.*

numerous lath-shaped or acicular inclusions in the mica crossing one another at angles of about 60°. These inclusions have been variously attributed to kyanite (G. Rose), rutile (Sandberger, Lacroix), and tourmaline (Rosenbusch). It is almost certain, however, that the striation producing this form of diffraction is much more minute than that caused by rods of recognisable inclusions.

The larger *inclusions* in mica are generally in the form of very thin plates lying between the cleavage sheets, though sometimes they cut through the bundles obliquely. The commonest of these inclusions are black, brown or red plates of iron-oxide, possibly magnetite, forming long strips or dendritic growths, having a regular crystallographic disposition with regard to their host the mica. Thin films of quartz, needles of black tourmaline, feathery, radiating plumes of red tourmaline, stout plates of garnet and stumpy crystals of green apatite have been observed in Indian muscovites.

Intergrowths of two varieties are quite common, especially intergrowths of biotite and muscovite. The junction line between the two varieties may be quite irregular, but the muscovite appears to be generally, if not always, outside and surrounding the biotite.

The *hardness* of mica varies between degrees 2 and 3 of Mohs' scale, being distinctly harder than talc, from which it can thus be readily distinguished. Mica itself varies considerably in hardness;

the smooth even sheets appear to be slightly softer than those which have been damaged by earth pressure, and a high degree of hardness is generally looked upon with disfavour in the trade ; it should be just possible to scratch the mica with the finger nail. The loss of hardness following hydrous decomposition is accompanied by reduction in strength, elasticity and consequent commercial value.

Although their remarkable physical characters mark the micas as a distinct and natural family amongst minerals, they vary so greatly in *chemical composition* that considerable difficulty has been experienced in discriminating the essential features in chemical constitution which are peculiar to the family and common to all its members. The subject has been elaborately studied by Tschermak (1878), Rammelsberg (1878-1889) and F.W. Clarke (1886-1889), who have expressed different views of the chemical constitution of the family.

Tschermak [1] regarded the micas as isomorphous mixtures of the following fundamental molecules—

$$K = Si_6\ Al_6K_2H_4O_{24}$$
$$M = Si_6\ Mg_{12}O_{24}$$
$$S = Si_{10}\ H_8O_{24}$$

Rammelsberg [2] considered them to be mixtures in different molecular ratios of the three silicates $R_2\ SiO_3$, $R_4\ SiO_4$ and $R_6\ SiO_5$, and divided them into an alkaline group and a ferromagnesian group.

Clarke [3] regards the micas, and in fact all such aluminous orthosilicates, as substitution products of the compound $Al_4\ (SiO_4)_3$ in which the Al-atom is successively replaced by an univalent (R) atom and Mg or other divalent metal. If we take magnesium as a generic representative of the bivalent metals, and give univalent elements or

[1] Tschermak, "Die Glimmergruppe: II Theil, Chemische Zusammensetzung", *Sitzber. Akad. Wien*, 1878, LXXVIII, 5–60.

[2] Rammelsberg, "Ueber die chemische Natur der Glimmer," *Sitzber. Akad. Berlin*, 14th February 1899, 99—109.

[3] F. W. Clarke, "A theory of the mica group". *Amer. Journ. Sci.*, (3) XXXVIII (1889), 384—393. See also same *Journ.*, XL (1890), 410 and XLI (1891), 242.

groups the general symbol R, we can imagine the following derivatives of $Al_4\ (SiO_4)_3$ as easily possible :—

I	II	III
$\mathrm{Al}\left\langle\begin{array}{l}SiO_4\equiv R_3\\ SiO_4\equiv Al\\ SiO_4\equiv Al\end{array}\right.$	$\mathrm{Al}\left\langle\begin{array}{l}SiO_4\equiv R_3\\ SiO_4\equiv R_3\\ SiO_4\equiv Al\end{array}\right.$	$\mathrm{Al}\left\langle\begin{array}{l}SiO_4\equiv R_3\\ SiO_4\equiv R_3\\ SiO_4\equiv R_3\end{array}\right.$
IV	**V**	**VI**
$\mathrm{Al}\left\langle\begin{array}{l}SiO_4\equiv MgR\\ SiO_4\equiv Al\\ SiO_4\equiv Al\end{array}\right.$	$\mathrm{Al}\left\langle\begin{array}{l}SiO_4\equiv MgR\\ SiO_4\equiv MgR\\ SiO_4\equiv Al\end{array}\right.$	$\mathrm{Al}\left\langle\begin{array}{l}SiO_4\equiv MgR\\ SiO_4\equiv MgR\\ SiO_4\equiv MgR\end{array}\right.$

To these we may add as the bivalent analogue of III, the compound $Al_2\ (SiO_4)_6\ Mg_9$ (VII). In the case of the fluorine-bearing forms R^1 is represented by the univalent groups MgF and AlF_2. Most of the micas, Clarke considers, can be regarded as intermediate mixtures of the above presumably isomorphous types. Thus No. I represents muscovite and paragonite ; No. VI some phlogopites ; Nos. II, V and VI are really unnecessary as types, being mixtures of pairs of Nos. I, III, IV and VII, whilst even No. IV may be regarded from the same point of view as superfluous. These formulæ are satisfactorily applicable to the micas which on analysis appear to be normal orthosilicates, but there are some in which the oxygen is in excess of SiO_4, and in these Clarke assumes the existence of AlO taking the part of R^1 and being the equivalent of $Al\ F_2$; in others the proportion of oxygen to silicon is lower than in SiO_4, and in these the polysilicic acid $H_4Si_3O_8$ is supposed to replace the (also tetrabasic) orthosilicate H_4SiO_4, giving rise to a set of circumstances paralelled amongst the plagioclase felspars in which albite ($NaAlSi_3O_8$) and anorthite ($CaAl_2\ (SiO_4)_2$) are apparently isomorphously replaceable.

In these three attempts to trace a chemical isomorphism corresponding to the evident physical similarities of the different members of the mica family, the existence of hypothetical compounds not yet found separate in Nature has been postulated; but Clarke's theory most nearly escapes the dangers of this method, and is supported by partial analogy with the felspar group. Clarke also asserts a similar form of

chemical constitution for the "micaceous" minerals like the vermiculites, chlorites, margarite and the clintonite group.

The four chief mica species—muscovite, lepidolite, phlogopite and biotite—fall into two groups chemically as they do when classified by their physical properties. The first two may be conveniently known as alumino-alkaline micas, already placed together on p. 16 according to their physical properties (Group I), whilst the last two may be distinguished as ferromagnesian micas, referred to before as Group II.

Of the alumino-alkaline group, muscovite is characterised by its high content of alumina and potash, whilst lepidolite contains lithia accompanied by a decided quantity of fluorine. In the ferromagnesian group, phlogopite is more essentially magnesian, whilst biotite is distinctly ferriferous. The variations are too great to permit the representation of a species by definite types; but the following formulæ and corresponding percentage compositions represent the most frequent type of each species:—

MUSCOVITE.	SiO_2	45·2
$2\,H_2O.\ K_2O.\ 3\,Al_2O_3.\ 6\,SiO_2$	Al_2O_3	38·5
	K_2O	11·8
	H_2O	4·5
		100·0

LEPIDOLITE.	SiO_2	51·3
$H_2O.\ K_2O.\ Li_2O.\ 3\,Al_2O_3.\ 6\,SiO_2$	Al_2O_3	18·4
$3\,K_2O.\ 3\,Li_2O.\ 4\,Al\,F_6.$	$Al\,F_6$	12·0
$2\,Al_2\,O_3.\ 18\,SiO_2.$	K_2O	13·4
	Li_2O	4·2
	H_2O	0·7
		100·0

BIOTITE.	SiO_2	39·9
$(H, K)_2O.\ 2\,(Mg, Fe)O.$	$Al_2\,O_3+F_2O_3$	22·9
$(Al, Fe)_2\,O_3.\ 3\,SiO_2.$	$Fe\,O$	16·0
	MgO	8·8
	K_2O	10·4
	H_2O	2·0
		100·0

PHLOGOPITE.
3 H_2O. K_2O. 7 MgO. Al_2O_3. 7 SiO_2.

SiO_2	44·2
Al_2O_3	10·8
MgO	29·4
K_2O	9·9
H_2O	5·7
	100·0

The micas may thus be looked upon as silicates in different proportions of alumina, the alkalies (mainly potash), iron and magnesia. Arranging the bases according to their quantity and importance their order is seen to be reversed in the two groups:—

I. ALUMINO-ALKALINE.		II. FERROMAGNESIAN.	
ilicates of	Alumina. Alkalies. Iron. Magnesia.	Silicates of	Magnesia. Iron. Alkalies. Alumina.

Muscovite is by far the most important of the Indian micas and the only one which has been worked to any serious extent, though the other three chief varieties also occur in quantity. The following two analyses of Indian mica, most probably from Bengal, shows the composition of the muscovite so largely mined and exported:—

	I.	II.
SiO_2	45·57	45·71
Al_2O_3	36.72	36.57
Fe_2O_3	0·95	1·19
FeO	1·28	1·07
MgO	0·38	0·71
CaO	0·21	0·46
K_2O	8·81	9·22
Li_2O	0·19	...
Na_2O	0·62	0·79
H_2O	5·05	4·83
F	0·15	0·12
	99·93	100·67
	Sp. Gr. = 2·831	Sp. Gr. = 2·830

I. Analysis by L. Sipöcz. 1873, *Tschermak's min. und petr. Mittheil.* p. 31.

II. Analysis by S. Blau . . *Ibid*, 1873, p. 32.

By calculating the sesquioxides as alumina, the protoxides as magnesia, and the alkalies as potash, and calculating to 100, we obtain the following as an average analysis, which, omitting the small quantity of magnesium fluoride, agrees nearly with the formula already given for typical muscovite, namely, K_2O. $2\ H_2O$. $3\ Al_2O_3$. $6\ SiO_2$:—

SiO_2	45·7
Al_2O_3	37·4
MgO	1·4
K_2O	10·4
H_2O	4·9
F	0·2
	100·0

Small crystals of various micas have been *artificially* prepared by various workers, notably by Hautefeuille and St. Gilles, von Chrustschoff and Doelter, whilst Vogt and others have recorded the formation of some varieties of this mineral in furnace slags. Artificial micas have never been, and are not likely to be, made in crystals sufficiently large to be of marketable value; but Doelter's experiments to test the action of sodic and magnesic fluorides on certain natural silicates are particularly instructive on account of the way in which they show the formation of mica at the expense of other silicate minerals. In this way Doelter has shown that the variety biotite can be made by the alteration of hornblende, glaucophane and garnet, a phlogopite from pargasite, whilst a muscovite-like mica was formed by the action of potassium fluo-silicate and aluminic fluoride on andalusite. The last-named result is of importance, as pointed out below (p. 39), on account of the way it partially imitates the conditions under which valuable muscovite appears to have formed in pegmatite veins.

III.—GEOLOGICAL OCCURRENCE.

The commonest occurrence of muscovite is as a constituent of granite, which may be so fine in grain that the individual minerals can be recognised only with a microscope, or so excessively coarse that the crystals may measure several feet across. The latter form, on account of the size of the crystals, is known as giant-granite or granite-pegmatite, and it more usually occurs in dyke-like masses, lenses or veins, not generally in the form of large irregular bosses like the commoner, massive, fine-grained granite.

The term *pegmatite* was originally proposed in 1822 by the French Abbé Haüy[1] for the peculiar intergrowth of quartz and felspar now known as graphic granite; but in 1849 the term was extended in meaning by Delesse[2] to cover coarse-grained veins containing silvery mica and often tourmaline, as well as quartz and felspar. The name thus became used to indicate the large size of the crystals irrespective of any peculiarity of structure, and lately its meaning has been used in a still more general sense to cover the coarsely crystallized varieties of other forms of plutonic igneous rocks like coarse-grained syenite, diorite, gabbro, etc., the variations in composition being indicated by the use of compound names, as granite-pegmatite, syenite-pegmatite, diorite-pegmatite, etc.[3]

The pegmatites which contain muscovite in large crystals are exclusively acid (siliceous) in composition, having in general the mineral composition of granite. The only pegmatites we are concerned with in connection with mica belong, therefore, to the class of granite-

[1] Traité de Mineralogie, 2nd Ed., Vol. IV, p. 436.

[2] Delesse, "Sur la pegmatite avec tourmaline de Saint Étienne (Vosges)." *Ann. des Mines*, 4th ser., XVI, 97.

[3] *Cf.* W. C. Brögger, "Die Syenitpegmatitgänge der sudnorwegischen Augit und Nephelinsyenite", *Zeitsch für Kryst.*, XVI, 1890. G. H. Williams, "General relations of the granitic rocks in the Middle Atlantic Piedmont Plateau," 15th Ann. Rep. U. S. Geol. Surv., 675 (1894). H. Rosenbusch, "Mikroskopische Phys. der mass. Gest., 1896, 492-497 and Gesteinslehre, 1898, 220.

pegmatites and will be referred to in the succeeding pages shortly as pegmatites.[1]

By far the majority of pegmatites are composed, like ordinary granite, of quartz, felspar and mica; but on account of the gigantic scale on which the crystals have developed, many comparatively rare minerals have been detected in pegmatites which have not been noticed in ordinary granites, possibly because of the small size of their crystals in the latter rock; others are possibly peculiar to pegmatites, and are due to the special conditions (referred to below) under which pegmatites have been formed. The following minerals have been noticed in Indian granite-pegmatites:—

Albite.	Lepidolite.
Allanite.	Leucopyrite.
Amazon-stone.	Magnetite.
Apatite.	Moonstone.
Automolite.	Muscovite.
Beryl.	Orthoclase.
Biotite.	Pitchblende.[2]

[1] Coarse-grained felspar-rocks (syenite-pegmatite) occurring near the village of Karutapalaiyam in the Coimbatore district, Madras Presidency, contain crystals of muscovite 3 to 4 inches across, associated with corundum, automolite and chrysoberyl, but the veins are not now worked for mica. These rocks and the associated elæolite-syenites are described in a separate memoir. (*Mem. Geol. Surv. Ind.*, XXX, pt. 3 (1901).

[2] The following analysis of pitchblende from the Singar mica mines, Gáya district, has been made by Mr. W. R. Criper, A.R.S.M., F.C.S., of Messrs. D. Waldie & Co., Calcutta:—

Oxide of Uranium	79·55
Alumina and oxide of Iron (containing ·35% P_2O_5)	3·35
Sulphide of Lead	9·90
Sulphide of Tin	1·20
Lime	·30
Magnesia	trace
Siliceous matter	2·30
Combined water	2·90
Salts of alkalies (by difference)	·44
	100

Cassiterite.
Columbite.
Epidote.
Fluor-spar.
Garnet.
Ilmenite.
Kyanite.
Quartz, pink and white.
Staurolite.
Tourmaline, red, blue, green and black.
Torbernite.
Triplite.
Uranium ochre.

The large size of the crystals, facilitating their extraction, makes some of these minerals, like the phosphates and felspar, worth attention from an economic point of view, whilst the most valuable constituent of all, mica, is of value purely because of the large size of the sheets it forms. Crystals or "books" of muscovite-mica have been obtained in Nellore district, measuring 10 feet across the basal planes, but usually, of course, they are much smaller, all gradations of size being obtained from those of marketable value down to scales of microscopic dimensions such as occur in the common massive granites.

Being the most delicate mineral in the rock the mica is the first to show the effects of crushing earth-movements, and large quantities of valuable mineral have by these means been destroyed; but it is on account of the remarkable stability of the Indian Peninsula, the geologically long and perfect quiescence it has enjoyed, that India is able to boast of the finest mica deposits of the world.

Whilst the Himalayan range is composed of rocks which have been crumpled and sheared even since late tertiary times, the Peninsula of India has remained as a firm solid mass since at least the lower palæozoic age, and as a result many very old rocks, like the pegmatites, have been preserved with remarkable freshness. The main mica-bearing area of the United States—the only area which has ever been a serious competitor with India for the first place in the mica market—owes its value to a similar cause: the crystalline mass with its included pegmatites, stretching from Georgia obliquely through the Carolinas to Virginia, presents to the contorted Appalachian range exactly the same relation as the Indian peninsula holds with regard to the

Himalayan chain—a firm, solid block of land against which the weaker part of the crust has been rolled up by tangential pressures.

Origin of pegmatites.

There is probably no other group of rocks whose origin has been the subject of more varied discussion than the pegmatites. De Saussure received the support of Credner, Klockmann, Dana, Huntington, Kerr and Sterry Hunt in likening them to metalliferous veins as the result of the successive deposition of mineral matter from solution in fissures, but recent researches support the earlier view of Charpentier (1823) who regarded the pegmatites as injections of granitic material which, originating in the still fluid granite, deep down, was pressed into the cracks of the already solidified granite and rocks above—"after-births," as it were, of the same granitic formation in the district in which they occur.[1]

Even before Charpentier's time, however, similar views were published by the old Cornish geologists, Carne, Davy and others, who distinguished between what they called "contemporaneous veins", which are related genetically to the granite which they accompany and often traverse, and the "true veins", filled with valuable ores and formed at a distinctly subsequent period by the chemical infilling of fissures.[2]

It is now generally conceded that pegmatites have resulted from the consolidation of injected fluid magmas, often directly traceable to some large granitic mass. This view, that they are merely contemporaneous injections of the residual granite magma, has been advocated by

[1] Charpentier, "Essai sur la const. géog. des Pyrenées", 1823, p. 158.

[2] Carne, "On the relative ages of the veins of Cornwall." *Trans. Roy. Geol. Soc. of Cornwall*, II (1822), 49. It is difficult to say who first used the term "contemporaneous veins". Dr. John Davy in 1818 (*Ibid.*, I, 20-26) referred to quartz veins traversing the granite of Porth Just as belonging "to that class of veins commonly considered contemporaneous". Those which were formerly called "contemporaneous veins" were in 1834 (Boase, "Primary Geology", p. 355) known as veins of segregation, a term introduced by Professor Sedgwick at the suggestion of Whewell "to express that they have been formed by a separation of parts during the gradual passage of the mineral masses into a solid state". This is the sense also in which the term "segregation" is used by Prof. H. Louis in the second edition of Phillips' "Ore deposits" (1896), p. 11, foot-note.

De la Beche, Bronn, Fournet, Durocher, Angelot, Naumann, Lehmann, Brögger, Reyer, Williams, Crosby and Fuller.

Recently evidence has accumulated to show that these residual portions of the granitic magmas, instead of being in a state of simple igneous fusion, contain much larger proportions of water than the average magma, and are consequently fluid at a very much lower temperature. Adopting the view expressed by Charpentier's expressive phrase, the hydrous condition of the magma injected to form these pegmatitic veins is capable of a simple explanation :—Most, perhaps all, igneous magmas contain water, and, as in the process of crystallization anhydrous minerals are separated, the water becomes concentrated in the residuary mother-liquor which can thus remain fluid at a much lower temperature. The injection of this aquo-igneous melt into the neighbouring rocks, or into fissures in the granite just solidified from the same magma, gives rise to the pegmatite veins.

With this view it is easy to explain also the coarse grain which is so characteristic of even the thinnest veins of pegmatite. The size of a crystal is directly dependent on the freedom of molecular translation within the molten magma (or solution) multiplied by the time during which molecular segregation is permitted. In a magma which becomes viscous on cooling, and in which the consolidation is rapidly accomplished, the crystals formed are necessarily small, as they always are for instance at the selvages of basic dykes, the converse being the case when the magma retains its fluidity for a long period. With what Reyer calls a *hydatopyrogenetic* (aquo-igneous) magma the latter condition is possible, for there is then a small difference between the temperature of the magma and of the rock into which it is injected, and consequently a very slow dissipation of heat. The reduction of temperature is still more retarded on account of the great specific heat of the water contained in an aquo-igneous melt; for to reduce water by one degree in temperature involves the equivalent rise of some three times the amount of average rock. The water, therefore, which becomes concentrated in the magmas that form our

pegmatites, explains the high degree of fluidity and consequent injection to great distances of very thin films, as well as the remarkably well crystallized condition in which such thin veins of pegmatite are invariably found.

It is to be expected, naturally, that the proportion of water to solid matter in the material which forms pegmatite veins will not always be the same, and, as a consequence, we get all stages between veins which are practically formed from igneous magmas, and which show the usual phenomena of more essentially igneous injections, and those which contain an excess of water and consequently approach chemical precipitations from solutions in fissures. The latter circumstance accounts for the occasional "comby" structures found in pegmatitic veins, whilst the former has given rise to the idea that pegmatites are essentially igneous in origin.

After a long period of sharp, not to say bitter, controversy between two opposed schools, geologists are beginning to recognise the fact that pegmatites are not to be relegated to either extreme explanation; but that the phenomena they present are due to a combination of both igneous and aqueous agencies, a conclusion which involves no difficulty since Guthrie and others have taught us to observe that igneous fusion and aqueous solution are not separated by a sharp line of demarcation, but, like many other natural phenomena, pass into one another by insensible gradations.

Form of pegmatite masses.

In India, as in the mica-mining areas of America, the pegmatites are found associated with mica-schists, quartzites and other schistose

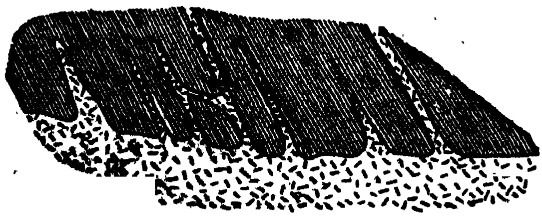


FIG. 8. *Pegmatite dyke cutting through the schists and sending out apophyses parallel to the folia (plan). E. of Gidhaur hill, Behar (after Mallet).*

rocks of the so-called upper division of the Archæan group. Into these schists the pegmatites have been intruded, generally along, but sometimes across, the folia, in the form of thin sheets, lenticular bodies, or large, thick, bosses (Plate VIII and figs. 8 and 9). The common disposition of the mica-bearing pegmatites in sheets seems to have been entirely overlooked by the miners in India, and ignorance

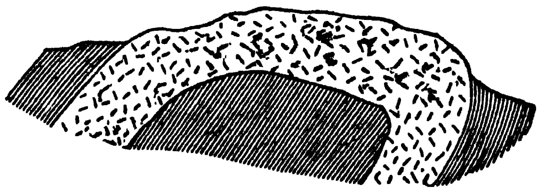


FIG. 9. *Section of pegmatite vein in mica schists, Sakri river, Hazáribágh district (after Mallet).*

of this fact is the principal cause of the exceedingly wasteful and primitive system of mining now being practised under European as well as Native management (see Chap. VI).

The general tendency of the pegmatite sheets[1] to follow the planes of foliation is probably due to the fact that this is the direction in which schistose rocks are more easily disrupted. Occasionally the pegmatite sheet changes its direction by following a fault plane before resuming its direction parallel to the schist folia. Where

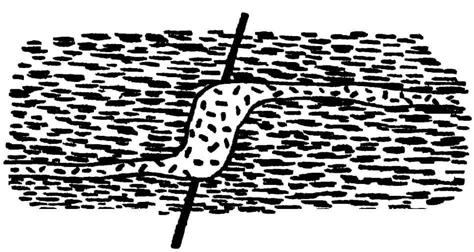


FIG. 10. *Thickening of pegmatite vein at a fault in the schists, Gáwan, Hazáribágh district.*

[1] The term "sheet" is more expressive than "vein," which gives one the idea of a more cylindrically shaped body. This appears to be the idea in the minds of the miners in the Behar area, who, by following the mica from "book" to "book," have made worm-like, tortuous excavations dignified in common talk by the name "mines". Reyer uses the term *Blatt* (pl. *Blätter*), leaf or sheet, instead of the commoner term *Gang* (pl. *Gänge*), vein (Theoretische Geol., 1888).

the sheet is so curved it is generally much thicker and carries larger sheets of mica than in the thin sheets (fig. 10). From sheets, uniform in thickness over large distances, we find various gradations down to small eye-like lenses, of which many may be found projecting from the schist surface over an area of only a few square yards, giving the impression that the pegmatite magma—the "granitic juice" as Zirkel would call it—has thoroughly impregnated the schists. Excellent examples of such occurrences are to be seen near Garanji (Ghorunjee) in the Hazáribágh district.

Many of the spaces occupied by the pegmatites are evidently of mechanical origin, the folia of the schists being forced asunder and left wrapping around the pegmatite-eye like the fibres of a piece of

FIG. 11. *Lenticular body of pegmatite with schist folia following its outline. Koderma, Hazáribágh district.*

timber around a flat wedge (see fig. 11). At the same time this explanation is not universally applicable, for we find pegmatite masses occupying positions in schists which have suffered no disturbance in the direction of their folia, and the pegmatites appear to occupy spaces formed by the absorption or removal of the schist material. There appears to be no other explanation applicable to stout ellipsoids or blunted lenses of the kind illustrated in fig. 12. Such occurrences are more characteristic of the larger masses of pegmatite.

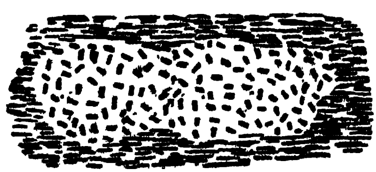


FIG. 12. *Pegmatite body in undistubed mica-schist, Gáwan, Hazáribágh district.*

The very frequent occurrence of valuable mica-bearing pegmatites in association with mica-schist is a circumstance worthy of note: the fact is important to the prospector and significant from the purely scientific point of view. More than once it has been asserted that in composition pegmatites vary with the rocks they traverse, and it has sometimes been rashly concluded in consequence that the minerals which compose the pegmatite have been derived by leaching out of the country rock and deposition of the materials in fissures.

The coarse-grained contemporaneous veins (pegmatites) which traverse diorites, syenites and granites are probably end-products of the differential consolidation of the magmas from which the associated massive diorites, syenites and granites are derived. In such cases, naturally, there is a mineralogical correspondence between the pegmatite vein and the rock it traverses, a correspondence not difficult to explain and one naturally to be expected. But as a matter of fact the best mica-bearing pegmatites, though having the mineral composition of granite, are not generally found traversing that rock. On the contrary, in the same area (take Gáwan in the Hazáribágh district, for instance), valuable mica-pegmatites will be found traversing the mica-schists, whilst worthless veins occur close at hand in the massive granite. That there is some essential connection between the mica-bearing characters of the schist and the pegmatite seems evident, and there are many facts to be observed in the mica-mining country which remind the observer of Doelter's artificial formation of muscovite by the action of potassium fluo-silicate and aluminic fluoride on andalusite.

We have found it necessary, in studying the physical conditions attending the injection of pegmatite magmas, to accept a compromise between the ultra-igneous theory and its antithesis. The writer considers it necessary also to accept a modification of the theory that mica-bearing pegmatites are the result of the simple consolidation of an injected magma, and to allow that, whilst the pegmatites have affected the surrounding schists, it seems likely that the schists in return have modified the composition of the pegmatites. The com-

position of the large masses of pegmatite cutting through the schists as clean dykes may be practically that of the magma which was injected; but in some places the schists are simply infested with numberless pegmatite-lenses and veins, as if the whole rock had been impregnated with the pegmatite juice, and, as far as mere composition is concerned, it is only necessary to introduce sufficient potash and possibly fluorine to account for the alteration of the aluminous and siliceous schists, to permit the formation of felspar, and to allow of its segregation with quartz and mica into the lens-shaped cavities produced by crumpling the schists. In our best mica-producing country we have large bodies of granite, with a few unimportant contemporaneous veins, protruding through mica-schists, which are full of pegmatite lenses, sheets and dykes. There is evidence that the granite is younger than the schist, intrusive into it and the cause apparently of a well-marked zone of metamorphism. It does not seem to be a wild supposition to expect that the vapours given off from such a granite-mass resembled in essential respects the reagents by which Doelter acted on andalusites. This mineral and its congeners, chiastolite, sillimanite and kyanite frequently occur in the schists, and various stages, from the commencement to the complete change of chiastolite into mica, are commonly observed.

There is an abundant evidence of fluorine in the district. Beside the muscovite, which contains this element, fluorine occurs more abundantly in lepidolite, fluor-spar, apatite and tourmaline. In some places, Ghorunjee for example, instead of mica-schist, the pegmatites are found cutting a granular quartz-rock with numerous large muscovite scales. Such a rock was presumably once a quartzite; but the granules of clear quartz are far larger than is usual in a quartzite, whilst the mica scales are certainly not of immediate detrital origin. The whole rock has evidently been recomposed, a process not improbably connected with the formation of the pegmatite. Experience teaches the prospector to look more hopefully at the pegmatites cutting mica-schists than those found in other "countries", and the circumstance suggests a genetic connection. But it does not necessarily follow that the

pegmatites were formed by the direct alteration of the schists; more probably the circumstances under which the pegmatite magma was injected permitted the permeation of the surrounding rocks with vapours which favoured their metamorphism with the formation of mica, and possibly also led to a modification locally in the composition of the pegmatite.

"Country" rock.

Pegmatites carrying valuable mica are not as a rule found traversing massive gneisses and granite. In India the only occurrences of value are found in the very composite group of schists, which are generally referred to as the upper division of the Archæan crystalline rocks, and are thought by some to be younger than the massive felspathic gneisses. The following types have been definitely determined in the "country" of Indian mica-bearing pegmatites:—

Compact quartzite.
Coarse granular quartz-rock with muscovite scales.
Quartz-biotite schists.
Quartz-schists with mica and kyanite.
Ditto with fibrolite.
Ditto with iron-ore.
Fibrolite-gneiss.
Chiastolite-mica schists.
Quartz-epidote gneiss.
Quartz-biotite-hornblende rock with large lumps of magnetite.
Epidiorite.
Hornblende-schist with garnets.
Ditto with scapolite.
Pyroxene-granulite.
Granulite (leptynite).
Diopside-gneiss with sphene.
Anthophyllite-rock.
Garnetiferous biotite-gneiss (biotite-granulite).
Ditto with octahedral magnetite.

Talc-schist and compact potstone.

Chlorite-schist.

Limestone and dolomite with chondrodite, wollastonite and tourmaline.

Ophicalcite and ophidolomite.

As an example of a section across a typical schist "country" containing pegmatites the accompanying section near the well-known mica centre, Koderma, may be given as one readily accessible for examination.

The two hills, Mowatand to the south-west and Banda to the north-east (fig. 13), are composed of a biotite-hornblende granite which is

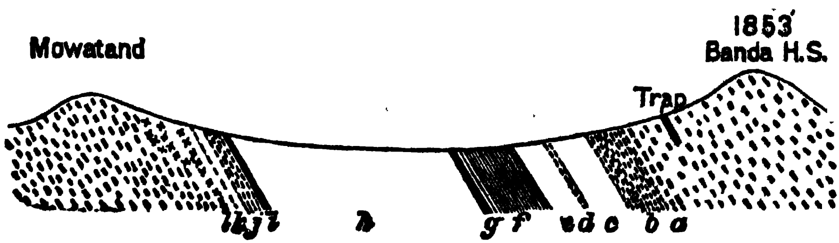


Fig. 13. Section through the schists north-west of Koderma, Hazáribágh district. Scale 2 in. = 1 mile.

foliated in conformity with the schists between. Near its junction with the schists there is generally a zone (*a*) of variable composition, apparently the result of contact action. Below this there is a zone of hornblende-gneiss (*b*) with garnetiferous felspathic bands; then comes mica-schist (*c*) including a band with large garnets, followed by hornblende-gneiss (*d*), and another band of mica-schist (*e*), in which pegmatite-lenses are common. Occasionally bands show biotite flakes an inch across and garnets as large as a fist. The next band (*f*) contains fibrolite, followed by a zone containing silvery mica and garnets, lying on mica-gneiss with fibrolitic bands and pegmatite sheets parallel to the folia. The schist bands are often only an inch or two thick and some contain lumps of magnetite; next occurs coarse biotite-gneiss with pegmatite. Then follows a thin bed of quartzite (*g*),

lying on a thick zone of mica-schists (*h*), some with felspar and white silvery mica, others with diaspore and talc, and bands with andalusite knots, the lowest beds in this zone being coarse mica-schist with pegmatite sheets. Under this follow in order a thin band (about 20 feet) of quartzite (*h*), hornblende-gneiss with pegmatite (*j*), flaggy quartz-mica schist (*k*), and a very thick band of graphic granite (*l*) with large lumps of magnetite, separating the schists from the well-foliated margin of the granite mass forming Mowatand hill. Pegmatite veins are very abundantly developed in this transition zone, but become less prominent as the hill is approached and the granite is less distinctly foliated. The granite of the two hills, Mowatand and Banda, occurs quite commonly throughout this mica belt, forming characteristic dome-like masses, from which fact it was referred to formerly as the "dome gneiss". It is, however, a true granite, presenting, along its borders, a well marked contact zone, and its constant occurrence near the large network of pegmatite veins suggests that the latter are the final products of the consolidation of the magma which gave rise to the granite.

IV.—GEOGRAPHICAL DISTRIBUTION.

Pegmatites are known at a very large number of places where the old crystalline rocks have been exposed in India. Presumably, large quantities of the same rock are also concealed by the extensive mantles of younger sedimentary strata and the great sheet of Deccan Trap. Nevertheless, the pegmatites are not always mica-bearing, or only contain mica in small and consequently valueless crystals. In the following pages only those occurrences are described which have yielded mica approaching a marketable size. Some of these, indeed most of them, have not been worked hitherto with profit; but it is undesirable to omit them from the list, for they have of necessity been exploited but superficially, and it is well to keep in mind every known occurrence of possible value.

A glance at the list of districts will show that the known occurrences of marketable mica are practically, and the paying localities strictly, confined to the Peninsula. The Extra-Peninsular portions of India are either covered with younger sedimentary deposits, or the crystalline rocks have been so thoroughly deformed by profound earth-movements that all large crystals of mica have been too seriously mutilated to be of commercial value. It has already been pointed out that our experience in India, which is capable of such a simple explanation, is exactly paralleled by the distribution of mica-mines in other countries: only the few areas which have withstood the folding movements of the past, and which appear to be specially stable portions of the crust, are being worked for this valuable mineral. The belt of crystalline rocks forming a stable *Vorland* on the eastern flanks of the Appalachian mountain range in the United States, and presenting to that mountain range a relation corresponding to that existing between Peninsular India and the Himalayas, is also rich in valuable mica and the most formidable competitor of India in this respect. Exploration of the great stable mass of Central and Eastern Africa will most probably reveal good pegmatites; the essential conditions of geological stability exist there on a great crystalline

mass very similar in many respects to Peninsular India, and it is hardly likely that such an area is devoid of mica-bearing pegmatites.[1]

The known mica-bearing areas are described in the following order:—

BENGAL PRESIDENCY.—
- Gáya, Hazáribágh and Monghyr districts.
- Sikkim-Tibet.

BOMBAY PRESIDENCY.—
- Chhota Udepur.
- Nárukot.

BURMA.

CENTRAL INDIA.—
- Rewah.

CENTRAL PROVINCES.—
- Bálaghát.
- Bastar.
- Biláspur.

COORG.

MADRAS PRESIDENCY.—
- Gánjám.
- Nellore.

MADRAS PRESIDENCY—contd.
- Nílgiris.
- Salem.
- Trichinopoli.
- Vizágapatám.
- Travancore.

MYSORE.

PUNJAB.—
- Bhábch.
- Gurgáon.
- Kángra.

RAJPUTANA.—
- Ajmere-Merwára.
- Jaipur.
- Kishengarh.
- Sirohi.
- Tonk.

BENGAL.

Gáya, Hazáribágh and Monghyr.

It is to the material obtained from the very productive belt which stretches obliquely across the junctions of Gáya, Hazáribágh and Monghyr that India owes its earliest reputation for mica. Portions of the deposits of this area have been described by Dr. P. Breton (1826), Dr. J. McClelland (1849), Capt. W. S. Sherwill (1851), Mr. F. R. Mallet (1874) and Mr. A. Mervyn Smith (1898). The writer has recently, with the assistance of Mr. H. H. Hayden and Lala Kishen Singh, made a re-examination of the whole belt, and takes this

[1] Since the above was written the Acting Vice-Consul at Dar-es-Salem has reported the discovery of good mica on the Uluguru and Ungun hills in German East Africa. (Diplomatic and Consular Reports No. 2568, 1901, p. 23.)

opportunity of recording his indebtedness for the information and assistance readily given by all the mine owners and managers, amongst whom he is especially indebted to Messrs. Hannay and Macfadyen of Messrs. F. F. Chrestien & Co., Mr. Mervyn Smith of the Indian Mica Coy., and Mr. E. Lane of Messrs. Macdonald & Co.

The mica-producing area roughly coincides with a great belt of schists and associated gneissose granite, which is some 12 miles broad and stretches for about 60 miles from Bendi in Hazáribágh district, through the south-eastern corner of the Gáya district, east-north-eastwards to near Nawadih (Jha-Jha) on the East Indian Railway in Monghyr. Along this belt over 250 mines have been opened, turning out annually about 450 tons of mica fit for export valued at about 9 lakhs of rupees (for details see Chapter VI).

The principal mining centres are :—

Place.	District.	Latitude.		Longitude.	
		°	′	°	′
Bendi (Bendee) . . .	Hazáribágh . . .	24	31	85	28
Charki (Churkee) . . .	Do. . . .	24	34	85	52
Dabúr (Doobour) . . .	Gáya	24	36	85	57
Dháb	Hazáribágh . . .	24	35	85	49
Domchánch	Do. . . .	24	28	85	44
Gáwan . . .	Do. . . .	24	37	85	57
Gharanji (Ghorunjee) . .	Do. . . .	24	34	86	11
Koderma	Do. . . .	24	28	86	38
Mahaisri (Muhaisree) . .	Monghyr . . .	24	43	86	19
Nawadih	Do. . . .	24	47	86	26
Rajauli (Rejowlee) . .	Gáya	24	39	85	33
Tisrí (Tesree) . . .	Hazáribágh . . .	26	10	75	56

The nearest convenient railway stations for most of the mines are Giridih on the East Indian Railway, 45 to 60 miles distant, Gáya about 20 miles from the north-west face of the belt, and Nawadih, now named Jha-Jha, 4 miles from the north-eastern end of the field. The largest quantity of material finds its way most conveniently through Giridih, to which the freight by road adds very seriously to the cost of the mineral, and is a serious tax on the industry. But the proposed line from Katrásgarh to Gáya will run through the mica-fields, and when constructed will be a great assistance towards the development of mining.

The schist belt forms an irregular scarp, with a series of gháts leading from the gneissic upland of North Hazáribágh to the Gangetic plain; the comparatively rapid action of the rivers has contributed to the irregularity of the surface-features, and has opened the country in a way which facilitates the detection of the pegmatite-veins as well as the processes of mining for mica. In this respect the Bengal mica-bearing belt possesses an advantage over the principal Madras field, which is situated on the flat, partly alluvial, plains of the Nellore district (see p. 59).

Prospects of the area.—Although the Bengal area has been worked for many years, and possibly the majority of available good veins have been attacked, the mining has been for the most part superficial, and there is no likelihood of early exhaustion. With a few exceptions the mines are very shallow, and most of them are mere worm-like excavations which have done practically nothing towards following the pegmatite sheets along the strike. Work has been carried only so far as the "books" of mica can be traced, and large quantities of pegmatite, containing doubtless mica as good as that removed, still remain untouched. The choice bits near the surface have been picked out, and the time has come for more systematic working with recognised modern mining methods. With the judicious outlay of sufficient capital, the industry is capable of indefinite development, and it appears to be altogether two early to consider the possible limitation of the resources of this field.

The dome-gneiss.—A striking landscape feature along this belt, and one which is of great geological importance, is the frequent occurrence of low, rounded hills of gneissose granitite, the "*dome-gneiss*" of earlier workers, so named on account of its peculiar habit of weathering into piles of dome-like hummocks and large, ellipsoidal masses of bare rock, in which the concentric surfaces, due to exfoliation by the action of sun and weather, form the most prominent divisional planes. The rock is sometimes porphyritic, and has generally a gneissose structure, due to parallel disposition of its inequiaxed constituents; but there is no definite banding due to alternating layers of dissimilar mineral composition, such as characterises the schist formation around. In mineral composition the "dome gneiss" shows the typical features of a granitite (Rosenbusch), being composed of quartz and microcline with smaller quantities of oligoclase, biotite, hornblende and accessory sphene, apatite and zircon. The prevailing colour of the felspathic constituents gives the rock a pink to purple tint. Besides its mineral composition, the rock resembles undoubtedly eruptive granites in the possession of autoliths formed by local concentration of its ferromagnesian constituents, contemporaneous coarse-grained veins, xenoliths of quartzite, and a well-marked zone due to contact-action near its junction with the schists. These features indicate an eruptive origin for the "dome-gneiss," and account for its appearance at different horizons in the schists, its occurrence in large roughly lenticular bosses, as well as in thin sheets intruded between the schist folia. As a consequence of this origin, its foliation planes sometimes underlie, and sometimes appear to rest on, those of the schists. Prominent and typical examples of the "dome-gneiss" are exhibited in the Nero hill, 1,737 feet, west of Domchánch (24°28′; 85°42′), Banda, 1,883 ft. near Koderma (24° 28′; 85° 38′), Maramoko, 2,052 ft., north-east of Koderma (24°34′; 85°43′), and Banresur, 1,739ft., north-east of Gáwan (24° 40′; 86°1′).

The fact that the pegmatites are most abundantly developed in the schists where the "dome-gneiss" is prevalent suggests a genetic relationship between the two, the most probable conclusion being that the

pegmatites have been formed from the end-products of the magma whose earlier eruptions produced the "dome-gneiss". That the "dome-gneiss is foliated, whilst the pegmatites are practically unaffected by earth-movements, does not necessarily imply any great differences in their ages: the amount of deformation suffered by the "dome-gneiss" is no more than might have been brought about during consolidation, and was probably provoked by its own intrusion between the schists; indeed, it seems likely that the last disturbance of the area was connected with this great granitic eruption, the pegmatitic end-product having found its way as a more mobile, aquo-igneous liquid into the smaller fissures amongst the schists, forming the final phase in the disturbance.

The schists.—Earlier workers, conforming to the prevalent theory of the time, distinguished the "dome-gneiss" as "metamorphic" and grouped together the associated schists under the term "sub-metamorphic." The peculiar features of the former can all be explained most easily as due to the deformation of igneous intrusions, and the changes are not profound enough to merit the use of the term metamorphic. The *schists*, however, represent rocks of various origins, which have been made crystalline, and in other respects altered, by the commonly recognised processes of metamorphism. Many, like the hornblende-schists, epidiorites and granulites, differ very little in composition from known igneous types, and probably represent lava flows, intrusive sheets, or even laccolitic intrusions. Others, like the rock near Gáwan containing anthophyllite, retain in places structures which characterise volcanic ashes, whilst the crystalline limestones, quartzites and chiastolite-schists indicate, by their chemical compositions, their origins respectively as limestones, sandstones and shales. These leading types are found in alternating bands of various thickness, representing by their variety the common differences observable in a great sedimentary system, whilst before, during, and possibly since, their metamorphism they have been so profoundly crumpled and folded, that it would be ridiculous to regard the apparently inferior beds to be necessarily older than those resting upon them:

no stratigraphical sequence can be established amongst these schists, and their value is appraised simply by their interest as lithological types.[1] A list of those so far recognised in the Indian mica-bearing tracts is given in Chapter II. Practically the whole of these occur in the Behar mica belt, and some of them have been recognised only in this area, which has had a more thorough examination, and is better dissected by atmospheric agents, than the other mica districts of India.

In his survey of this belt, Mr. Mallet distinguished three stages amongst the schists, an upper stage composed of quartzites as seen in the Mahábar hill, a thick middle stage in which mica-schists largely predominate, and a basal member in which quartzites again prevail, and, as in the Bhiaura ridge, are sometimes very strongly developed. Mr. Mallet was compelled by the general theory then prevailing to regard these rocks as younger than the associated "dome-gneiss," yet, with characteristic faithfulness, he recorded numbers of facts giving no support, and, in negative evidence at least, often conflicting with, his interpretation of the phenomena. His map, which is a remarkable piece of patient skill, shows a very intricate boundary between the schists and the dome-gneiss, whilst he states that the foliation planes in both rocks are found to follow the intricate twistings of the outline. The formation distinguished by him as the lowermost member of the schist-group is shown on the map as a narrow mantle wrapped around each protuberant mass of dome-gneiss. Microscopic examination of this mantle reveals far more than quartzitic rocks as they so often appear to be in hand-specimens: it displays many phenomena characteristic of igneous contact, and with the conclusion that the "dome-gneiss" is in reality an intrusive granite, younger than the schists, these phenomena at once become intelligible, and the difficult facts mentioned by Mr. Mallet are explained.

Accessory minerals.—In a few places minerals of economic value other than mica occur, and in some cases might be made accessory to the mica industry, though probably none of them is sufficiently abundant to found independent industries. The *oxides of iron* occur in quartzose schists similar to those better known in the South of India,

and heaps of iron-slag in many places show that in the past a considerable industry existed; the *Kols* still in a casual way smelt a certain amount of iron in a bloomery, which is essentially similar to that employed for the direct process by other out-caste tribes of India. Much of the ore used is obtained by washing river-sand, and there are cases recorded of the accidental production of tin from the ore so obtained. In his geological notes on part of Northern Hazáribágh, Mr. Mallet mentions an instance of this, and the writer has lately had an opportunity of confirming the story by chemical examination of the furnace-products obtained through Mr. Mervyn Smith from the iron-smelters near Bendi. Although, on account of its greater specific gravity, cassiterite concentrates by washing even in the presence of iron-ore, the observations recorded above should warrant a careful watch for larger deposits of the mineral. According to Mr. Mallet's account of the ore discovered, and for a short while worked, near the Barákar river, eight miles west of Giridih, the tin-stone occurred in lenticular bands in the gneiss which, judging by the habits of cassiterite, were not improbably granitic veins. Isolated grains of cassiterite are often found in lepidolite near Pihra (24° 38′ 30″; 85° 51′), where its association also with indicolite and other forms of tourmaline and fluor-spar is in agreement with its occurrences in other parts of the world.

To a small extent it may be found possible to utilize as bye-products the *phosphatic minerals* occurring in the mica-bearing pegmatites. Pale-green *apatite* has been found in several localities, the most abundant being in the Lakamandwa mine near Koderma, where the schists surrounding the pegmatite-vein are also impregnated with phosphate of lime. An experiment was made by the writer to test the abundance of apatite obtainable from the waste material thrown out by the miners from the Lakamandwa mine. Three boys were shown specimens of the mineral, and for a pay of 4½ annas picked out, in 7 working hours, 100 lbs. of the mineral from the fresh waste. A much larger quantity might have been obtained if the boys had been practised previously in recognising the mineral, and still more if the mud and soft mica films which coated the apatite had been

washed from the waste heaps. The experiment almost certainly, therefore, produced a result less favourable than would be obtained by proper organization in regular practice. As it was, the material so obtained was found to contain, on careful chemical analysis, 76 per cent. of phosphate of lime, or 82·5 per cent. of apatite, an amount which certainly more than repays the cost of labour, and would probably leave a decided margin after meeting the cost of royalty, packing and freight to Calcutta. The industry must always be a small one, and the mineral does not occur in sufficient abundance to warrant mining for it alone; but at present it is thrown away with the waste, and might very well be turned to some account as an addition, however small, to the returns of a mine which is worked primarily for mica.

Another occurrence of phosphate, interesting because of its rarity elsewhere but probably of small value as a source of phosphoric acid, was noticed to occur as considerable masses of *triplite* near the remarkable mica mine, 2 miles south-east of the village of Singar (24° 35; 85° 35′) in the Gáya district. The mineral is a phosphate and fluoride of iron and manganese, containing about 32 per cent. of phosphoric acid. The locality from which the triplite was obtained also yielded small specimens of the more valuable mineral *uraninite* (pitchblende), associated with *uranium-ochre* and the beautiful *torbernite*, a phosphate of uranium and copper.

Amongst other minerals of casual value or interest might be mentioned the *leucopyrite*, an arsenide of iron, occasionally found in lumps several pounds in weight in the mica-bearing pegmatites, near Dábur, south of Gáwan on the Sakri river, and again one mile south-south-west of Dháb; transparent, green *tourmaline*, sometimes suitable for optical uses, near Manimundar (24° 37′; 85° 52′) where it is associated with the blue variety, *indicolite*, and *lepidolite*; and *columbite*, the tantalate and niobate of iron and manganese, found in large quantities in a mine 4 miles south of Nawadih (Jha-Jha) in the Monghyr district. If there was any market for a porcelain industry, an abundance of clean *felspar*, now rejected, would be available in any part of the mica belt; but kaolin does not occur in any abundance.

In some places, near Ghorunjee for instance, and also near Bagjunt, the felspar shows the peculiar opalescent appearance of the moonstone, and small fragments might be used for cheap jewellery. Pale-blue and pale-green *beryls* have been found in several localities, and in one mine, near Muhaisri in Monghyr district, a crystal 9 inches in diameter was found to include large, transparent and flawless fragments of a pale-green colour. The peculiar tint of the aquamarine was often observed, but not in transparent beryl. Crystalline, dolomitic *lime-stones* occur near Gáwan, and at Dhelwa, 5 miles further north; whilst small fragments of *noble serpentine* were found associated with the dolomite at the latter locality. *Garnets* are common throughout the district, and some of those in the coarse, flaky biotite-schist have the correct colour, though they are rarely clear enough, for the manufacture of cheap jewellery.

Details of the methods employed in mica mining and the preparation of the mineral will be found in Chapter VI. Nearly every occurrence of valuable pegmatite has its peculiarities in the relations of the mica to the other constituents; but the variety is too great for detailed description, and the veins present no common character which would be of general use as a guide in exploitation. In some cases the hanging-wall, in others the foot-wall, contains the best mica, whilst in many instances the whole vein has to be worked out in order to secure the uniformly distributed "books": the special features of each vein must be settled in every particular case by intelligent prospecting; there is no rule to supersede common sense.

There is one feature in this area which is certain to inspire the curiosity of those interested in its geological features, although it has no necessary connection with the mica-mining industry. The well-marked ridge running for about three miles parallel to, and on the north-east side of, the railway line near Nawadih station, is composed of a peculiar breccia, which, at first sight, resembles a broken and recemented hornstone. Another row of small hillocks, made of the same material, rises above the cultivated soil further to the north-north-west,

the whole series lying along what appears to be a fault plane. No satisfactory explanation for the peculiar structure of the material presented itself when these rocks were first examined; but near Nargujoo, 6 miles further to the south-east, gradations from ordinary "strain-slip cleavage" were traced into a structureless mylonite resembling the material of the breccia near Nawadih. The phenomena near Nargujoo strongly recalled the features of the so-called "trap-shotten" gneiss of South India, which has been shown to be due to mylonisation of the charnockite series along dislocation-planes.[1] Even with the teaching of the sections at Nargujoo, and the knowledge of similar phenomena elsewhere, the breccia near Nawadih is not easy to explain with confidence, for in some places it is quite 400 yards thick; no other explanation, however, at present offers itself.

Sikkim border of Tibet.

Lieutenant-Colonel L. A. Waddell, I.M.S., states that mica in considerable quantities is quarried near Tinki, three days' journey from Giagong at the head of the Lachen valley, about six or seven miles below the line of perpetual snow.[2]

BOMBAY PRESIDENCY.

Chhota Udepur.

The Political Agent of Rewa Kantha reports the occurrence of mica-deposits in the Gabadia hills, within three miles of Chhota Udepur town, which is 22 miles from Bodeli railway station on the Daboi-Bádharpur branch of H. H. The Gāikwar's State Railway. The locality has not, however, been submitted to expert examination.

Nárukot.

Major G. Fulljames directed attention in 1852 to the mica obtainable in the village of Dholasadra, south-west of Jambughoda and

[1] Holland, The Charnockite Series. *Mem. Geol. Surv. Ind.*, Vol. XXVIII, 1900, p. 198 *et seq.*

[2] "Among the Himalayas," 1899, p. 408.

six miles north-west of Bodeli railway station. The mica is said to be of small size, but the locality has not been critically examined.[1] The area within which both the above occurrences of mica are said to be exposed is occupied by a tract of the transition rocks distinguished as the Champaner beds, which pass by an apparent transition into gneissose rocks, possibly bearing the same relation to the Champaner beds as that found so often elsewhere to be the case when schistose rocks come into contact with granitoid gneisses.

BURMA.

Leases have been granted for mica mining near Ye-nya-u in the Thabeitkyin township, *Ruby Mines district*, and a small quantity of the mineral has been raised. Specimens have also been found on the road between Sakaw and Nanyetseik in the *Myitkyina district*; eight miles east of Manwe on the Indaw stream, near the corundum quarries, and on the Shwedaung Gyi hill at the exit of the stream from the Indawgi lake.

CENTRAL INDIA.

Rewah.

Muscovite, in sheets 4 to 5 inches square, has been found at Bardghatta on the Rehr river in the Singrauli iláqa, but the specimens sent by the Political Agent were damaged by pressure-figures, and were stained by dendritic inclusions. The latter, however, is not a serious fault, and the veins should be more thoroughly exploited for mica, as we know, from Mr. Mallet's description of the Singrauli crystalline rocks, that the geological conditions resemble in all essential respects the productive belt of Behar.[2] In Singrauli there is a development of the composite schists and gneisses, not unlike those of Behar, following the northern fringe of the massive gneisses. The foliation-planes have a general trend of west-south-west to east-north-east in the direction of the Behar mica-belt, which is but a continuation of the same series, the intermediate portions being covered by a

[1] *Selections, Rec. Bombay Govt.*, No. XXIII, p. 101.

[2] *Cf.* Manual Geol. of India, 2nd Ed., pp 30 and 31.

southward trespass of Gangetic alluvium. In addition to the similarity in the schists there is a considerable development of schorlaceous pegmatites in the Singrauli area, but whether these are provided with mica crystals of sufficient size or not is a point to be determined by prospecting, which would, judging by the superficial geology, be a reasonable venture. The village of Bardghatta is within a mile to the south-east of Pipra, which is famous for its great corundum bed.

CENTRAL PROVINCES.

Bastar.

Mr. P. N. Bose, Deputy Superintendent, Geological Survey of India, found in 1899 muscovite plates measuring 4 to 5 inches across in a coarsely crystallized, granitoid rock, exposed in the Baordhig river, south of Jugani, four miles north of Lanjura Thana. The mica obtained was damaged by gliding-planes, but the specimens were from a weathered outcrop, and the vein would possibly yield better results on excavation.[1]

Bilàspur.

A certain amount of prospecting has been undertaken at Komochoki, and although the pegmatite-veins are numerous in this area, the mica so far yielded has not exceeded 2 inches square, and is of second-rate quality.[2]

Bálaghát.

At Chitadongri and Bamni an experimental lease for mica-mining was granted in 1869, but the material raised does not appear to have given plates exceeding $2'' \times 4''$. There are still old workings to be seen in the Baihar subdivision of this district.[3]

COORG.

The central portion of Coorg is occupied by a complex group of schists, named provisionally by the writer the Mercara group, and

[1] Private communication with specimens.

[2] Private communication with specimens.

[3] C. Grant, Gazetteer of Central Provinces, 1870, p. 18.

similar in character and origin to the schists with which the mica is found in Nellore and in Bengal. Pegmatite-veins are occasionally found in the Mercara schists, and towards the south-eastern end of the belt, near Pollibetta, these have been found to carry muscovite, which, though excellent as regards freshness and elasticity, is often damaged by pressure-figures and is warped. The rocks are largely covered by cultivation of the thick soil-cap for coffee-growing; consequently the exposures are very few, and only traceable for short distances. Two definite occurrences of mica in sheets of marketable size have been opened up near Pollibetta. On the Beechlands Estate, Mr. H. G. Parsons obtained pieces 6 to 8 inches square, some of it, but a very small proportion, of excellent quality. On Elk Hill, Mr. J. Chisholm obtained much larger pieces from a pegmatite-vein in his estate. Six lots of these sent to London were valued by a firm of mica brokers, and were estimated to be worth from a few pence to 8 shillings and 6 pence a pound. The mica was cut to rectangles measuring 12″ × 14″, 9″ × 12″, 6″ × 9″, 5″ × 7″, and various sizes of narrow ribbons. The results obtained by this experiment are very encouraging, and, as long as the vein can be definitely traced, it might be advisable to sacrifice the coffee land for mica-mining; but it would be highly indiscreet to destroy good coffee land for mere prospecting operations, as pegmatites in schists so disturbed are likely to be very hysterical in their behaviour. Like the pegmatites of the Wainád, further to the south-east and probably in an exposure of the same formation, those of Coorg are remarkably free of accessory minerals. Garnets occur, but no trace of schorl, which is so common in Bengal and Nellore, has been found.

The London brokers, noticing a few plates amongst the samples striated and damaged, concluded that the defects were caused or aggravated by blasting; but unfortunately such is not the case: the striations that I have examined all conform to the pressure-figure (see p. 18) and must have been produced by the stresses suffered during earth-movements. Consequently, precaution and care in mining will not rid the mica of these defects, which must always contribute

seriously to the proportion of waste. Notwithstanding the common opinion to the contrary, the mere shock of blasting does not generally injure mica.

There are some very interesting features in the Coorg pegmatites showing that earth-movement, occurring during the time when the pegmatites are consolidating, may give rise to phenomena often mistaken for subsequent crushing of the solid rocks. Fig. 14 represents a section through a specimen composed of muscovite and quartz. The former mineral is in a well-defined crystal which has been faulted out along its basal cleavage-surfaces like a pack of cards, but is otherwise undamaged. The quartz, when examined by the microscope in polarised light, is found to be in the form of very minute granules which are independent crystals, and the granular portions form tongue-

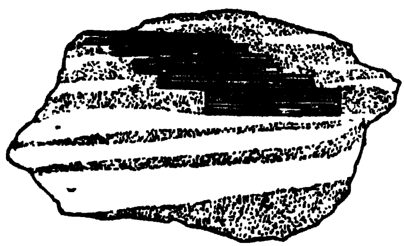


FIG. 14. *Faulted crystal of muscovite in quartz granulated by movement during crystallisation.*

like, sugary-looking streaks between clearer layers which are crystallized on a larger scale. From a sample of the quartz alone one would naturally suppose that the mineral had at one time been all as clear and transparent as the glassy patches, and that the sugary structure of the white tongues had been produced by crushing. But the mica, which, compared with quartz, is a very delicate mineral, would never have been preserved so little damaged if the crushing had occurred when the quartz was solid. Now it is certain, from the fact that the mica crystals have their crystal outlines perfectly developed, that the

mica crystallized before the quartz when the rock was formed, and was solid when the quartz was still in a liquid or viscous condition. As the magma from which the quartz finally crystallized probably passed through a long viscous stage, it is natural to infer that the mica-crystal was dislocated and faulted out by movement of the viscous material, and disturbance of this material during the crystallization of the quartz would result in the formation of crystals from numerous centres, whose growth would soon give rise to mutual interference, and produce a minutely granular mass in which the more prefectly crystallized portions would be embedded as clear bodies in a sugary matrix.

MADRAS PRESIDENCY.

Coimbatore.

An unsuccessful attempt was made to work the muscovite occurring associated with corundum, chrysoberyl and a zinc-alumina spinel in the peculiar, coarse felspar-veins (corundum-syenite pegmatite) exposed near the small hills of elæolite-syenite near Karutapalaiyam, 3 miles north-west of Kangayam in the Coimbatore district. The numerous pegmatite-veins in this area, and near the village of Padyur, a little further to the north, often contain good muscovite-crystals, but they are not sufficiently large and abundant to pay for mining mica alone.[1]

Ganjam.

The Collector of the district reports the occurrence of poor mica at the following places—4 miles north and 2 miles east of Rayagada and Guma hills of the Parlakimidi estate; Sisunda and Jillundi in the Gumsur taluk.

Nellore.

The mica-mining area in the Nellore district differs from that of Bengal in an important physical feature. In Bengal, as already ex-

[1] Described in a separate memoir. *Mem. Geol. Surv. Ind.*, Vol. XXX, part 3 (1901).

plained (p. 46), the schistose rocks form a scarp with its ghâts leading from a gneissic upland of from 1,000 to 1,500 feet down to the Gangetic alluvial plain, and the schist belt is consequently a region of erosion. In Nellore, on the other hand, the schists with their included pegmatites are found in the low-lying plain, forming the area on which the Penner and Swarnamukhi rivers, running eastwards from the Veligonda ridge, made by the Cuddapah quartzites, deposit their alluvium. Much of the mica deposits of Nellore are consequently concealed by sub-recent and recent formations and will never probably be detected although it seems likely, from the mica already raised, that the pegmatites are more valuable than those of Bengal. Mining too, on account of the flat surface, is generally more expensive than that permitted though little practised, in the hilly ground of the Bengal mica belt. An account of the methods pursued will be found in Chapter VI.

The mica mines of this district have been worked for very little more than a decade, and before the development of the industry the country had been only cursorily examined. The general geological features were mapped and described in outline by the late Dr. W. King in 1880.[1] Dr. H. Warth examined the mines being worked in 1891 and described the workings at Inikúrti (Podalakur, 14°22′; 79°48′) and Útkúr (14° 14′; 79°48′) in a special report to the Madras Government.[2] The industry has, however, considerably developed since that date, the mines now being worked numbering over 30. In 1898 the writer, accompanied by Dr. Walker, made a tour through the mining area, and the latter has since made a detailed examination of its geological features of which the following is a summary.

Geology.—The region specially examined by Dr. Walker extends from the fourteenth to the fifteenth parallel of north latitude, and from about the longitude of Nellore west to the Veligondas, a width of thirty

[1] *Mem. Geol. Surv. Ind.*, Vol. XVI, part 2.

[2] *Proceedings of the Board of Revenue (Madras)*, No. 279, dated 10th June 1892.

to forty miles (fig. 15). Geologically this field is composed of a central

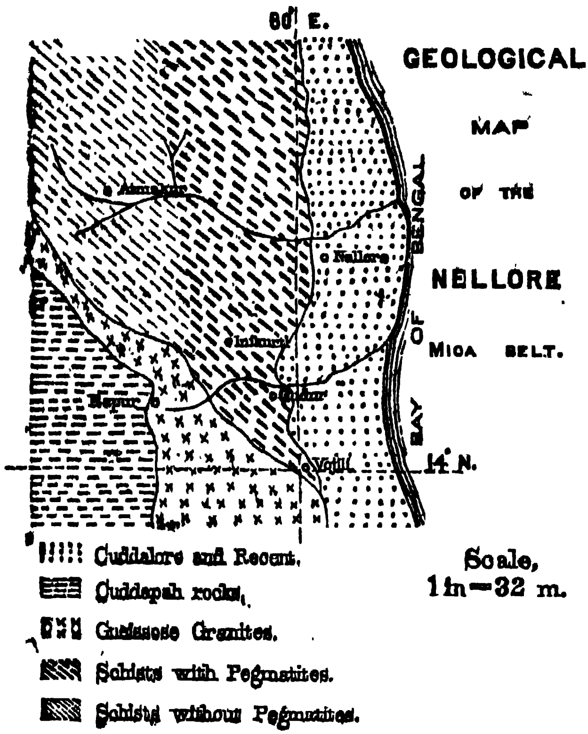


FIG. 15.

V-shaped fundament of well-foliated gneisses, the angle of the V being situated near Vojili (see fig. 15), one of the arms passing nearly due north past Nellore and Kavali, while the other arm goes in a north-west direction past Saidápuram and Udayagiri, and between this schist complex and the Bay of Bengal the surface rocks are of comparatively recent origin, none being older than the Rajmahal plant beds. On the west the gneisses are bounded by an area of igneous rocks, gneissoid granites and traps, or by the Cuddapah system of formations which make up the Veligondas. The eastern half of the schist complex is traversed by a large number of intrusive sheets and lenses of pegmatite often very rich in muscovite of great economic value. This constitutes

the mica belt. The whole of the schists and the rocks to the west of them are in turn intersected by one, or possibly two, series of dykes, generally of olivine-free diabase, though some dykes are of beautifully fresh olivine-diabase with well developed ophitic structure. Recent formations, such as laterite, kankar and alluvium, conceal the older rocks in most places, so that opportunity for geological observation is very limited. The general strike of the rocks varies from west-north-west to north-north-west.

South of the Penner river the rocks of the *schist complex* are largely well-foliated biotite and hornblende-schists, at times containing nearly enough felspar to be called gneisses. Talcose and chloritic schists are chiefly confined to one band dipping at high angles, and extending past Saidápuram and Orupalle to the north-west for a considerable distance. These latter schists are generally garnetiferous and frequently kyanitiferous, whilst the talcose band near Saidápuram becomes massive in some places and is then of value as a potstone. Very prominent, but really of relatively small volume, is a series of narrow quartzite bands, which, having resisted the denuding forces better than the surrounding softer schists, stretch across the country in conspicuous narrow ridges, often lending variety to an otherwise ill-decked landscape. North of the Penner, biotite-schists and quartzites give way to the hornblende-rocks, which are on the whole more massive than to the south.

East of a line joining Cháganam (14°13′; 79°45′), and Yerraballe (15°; 79°40′) pegmatite masses in the schists are of frequent occurrence, though no petrological or structural feature has been observed sufficient to account for the abundance of the mica-bearing rocks in the eastern half of the schist complex and their complete absence in the western half.

The younger rocks between the schist complex and the coast are principally *alluvium* and blown sand, with a narrow band of *Cuddalore sandstone* and an occasional exposure of *Rajmahal plant beds*. The schist complex is mica-bearing practically up to the western boundary

of this younger envelope, and it is unknown, of course, how much valuable material is so hidden by these deposits.

A grey *gneissoid granite*, at times hornblendic, at other times containing both micas so as to become a normal granite, and large, ill-defined masses of hornblende-plagioclase rock intervene between the schist complex and the Cuddapah rocks which form the Veligondas.

Near Gilakapad (14°15′; 79°40′) an interesting *quartz-porphyry* was found. Two narrow aphanitic dykes of diabase run east and west intersecting the quartz-porphyry.

The *diabase-dykes* which are seen in frequent outcrops throughout the district are most abundant towards the west in the vicinity of Rápúr. They are sometimes augite-plagioclase rocks and sometimes olivine-diabases.

Laterite very often forms the surface rock along the east of the schist complex, while to the north of the Penner river in the mica-belt, *kankar* is very abundant, being as a rule of the same distribution as the hornblendic rocks, from which it is very probably derived. A few miles east of Káligiri a long narrow ridge borders the Káligiri-Kávali road on the north side. This ridge is peculiar in that it is composed of well-rounded quartzite boulders, while elsewhere the loose rocks are almost always angular or sub-angular. As it is generally supposed that at no very distant geological time the sea extended inland to the Veligondas, it may be that this ridge owes its origin to the action of the sea on a former quartzite outcrop whose rocks were broken and rounded by the action of waves on the beach.

The *pegmatite masses* are generally in the form of intrusive sheets or dykes following the foliation of the schists, very rarely cutting across the folia. At times the dykes are of considerable thickness though some of the very thick masses are lenses, and still others are of indefinite form. They are most frequent in schists dipping at high angles. No well-defined contact action has been observed, though

generally the central parts of the pegmatite masses are more acid and coarser than the borders. This is well illustrated by the way in which mica is found more abundantly in the outer zones of stock-like masses or lenses than towards the centres of them.

The pegmatites are often very coarse and not infrequently quartz and felspar are intergrown in the form of graphic granite, a form apparently not favourable for the formation of good mica. The felspar is, as a rule, microcline, cleavage fragments of half a cubic foot having been often observed on the waste heaps. The microscope shows that the glassy quartz is composed of large, interlocking individuals, usually free from pressure or strain. Tourmaline, garnets, apatite, beryl and columbite are prominent accessory minerals.

Mining prospects.—By far the largest mica-crystals obtained in India have been discovered in this young mining district, where the pegmatite so frequently occurs in large stock-like masses. In the Inikúrti mine, first successfully opened by Mr. E. H. Sargent, crystals of mica were found measuring 10 feet across the basal planes and up to 15 feet across the folia. Rectangular sheets, perfectly free of cracks and flaws, have frequently been obtained measuring 30″ × 24.″ It is difficult to predict the future of such an area: probably not a tithe of the available pegmatites have been detected, and much of the material may never be found under the thick coat of laterite, recent alluvium and sub-recent sandstones, for mica is a mineral which cannot be prospected for by borings. Nellore is a district in which, above many others, the regulations for prospecting might be advantageously relaxed without necessarily neglecting to claim the full tithe of rights when actual mining commences.

History.—Mining for mica in this district commenced in a small way in 1887 when the attention of the Madras Board of Revenue was called to the practice, and the Collector of the district was authorised to auction the rights in specified localities for periods of two years.

The sale of the mines was delayed till September 1888, pending receipt of the form of lease to be executed. Three mines, one in each

of the villages of Útkúr, Podalakur and Chágaaum, were put up to auction, of which only the one in Útkúr, about 5 acres in extent, was purchased in October 1888 for Rs. 75 per annum.

Subsequently, in April 1889, Mr. Lonsdale of Bangalore applied for and obtained the lease of 10 acres in Podalakur (which at the auction-sale of September 1888 did not find bidders) at an annual rental of Rs. 250. The lease was subsequently cancelled on the application of the party that he was satisfied of the non-existence of mica in the piece of land taken up by him.

In 1890 there were two applications, one from Mr. Sargent for the piece of land given up by Mr. Lonsdale in Podalakur, and the other from a native of the district for three blocks of land, one in each of the villages of Sydápuram, Chágaaum and Útkúr, aggregating 10 acres. They were granted to the applicants at an average yearly rental of Rs. 50 per acre. The mine which was sold in 1888 for Rs. 75 per annum having yielded good mica, and the lessor being credited with having made large profits, there was undue competition for it when the term of lease expired in November 1890. It was put up to auction and fetched so much as Rs. 3,005 as yearly rental. This was followed by a very large number of applications by speculators for strips of land selected by them from surface indications, and it was thought best to auction them. They were sold in February 1891, and were purchased at high prices. Soon after purchasers found that they could get no mica of marketable value from the land, and all of them, with one exception, applied for cancelment of their leases, on which they had already paid considerable sums.

After such a number of failures applications for rights to mine mica became very rare, but Mr. Sargent continued work at Inikúrti with such marked success that interest in the industry revived again, and during the year 1898 the Government of Madras granted in this district as many as 71 leases for mining mica, amounting to 2,442 acres, whilst the sales from Government lands now bring in some Rs. 35,000 in royalty annually.

Nílgiris.

Mica-bearing pegmatites occur at numerous localities in south-east Wainád,[1] the chief localities hitherto recorded being—

Gudalur.	Pandalur.
Devála.	Cherambádi.
Nellakota.	

The best mica has been found in the neighbourhood of Cherambádi, where it is being mined by Mr. W. Morres on Naiken Shola and by Mr.W. MacKinlay on the Llewellyn Estate. Fairly large sheets of good quality have been found at the other localities, mostly, however, on the surface, and further prospecting will be necessary before their value can be determined.

At Cherambádi the mica is ruby-coloured of high quality, and occurs in considerable masses in the pegmatite-veins with quartz and felspar. Accessory minerals are very rare, only garnet and biotite having been identified. The trend of the veins corresponds with the strike of the foliation of the country rock, and is usually east-north-east to west-south-west, crossing the strike of the auriferous reefs at a high angle.

In all the pegmatite veins examined there is a peculiarly similar and persistent grouping of the constituent minerals. The quartz occurs in great wall or dyke-like masses, while beside it are masses of almost quartz-free felspar usually altered to a very pure, white kaolin. Between this kaolin and the quartz, the mica occurs in large "books," frequently found adhering to the quartz. The mica and felspar occur as a rule only on one side of the quartz (fig. 16).

The total thickness of the pegmatite bands seldom exceeds eight feet.

[1] This account of the mica-bearing localities in the Wainád is by my colleague Mr. H. H. Hayden (*see* also General Report, Geological Survey, India, 1899-1900, pp. 56 and 57).

So far, mining has been carried on only at Cherambâdi by Messrs. Morres and MacKinlay, but the quality and size of the mica would justify fairly extensive operations.

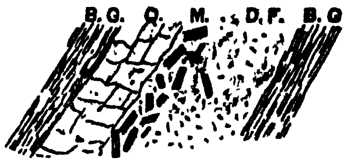


FIG. 16. *Section showing the common structure of the pegmatite veins in south-east Wainâd.*

Sheets of mica have been obtained up to 3 feet in length, but as the workings have at present only reached depths of a few feet below the surface, much of the mica now obtained has suffered from weathering. In spite of this, considerable quantities of mica of high quality are being obtained, and when mining has been carried to greater depths and into fresher rock, the quality will no doubt improve.

Owing to the almost entire absence of accessory minerals, the larger plates are not spoilt, as is so frequently the case elsewhere, by inclusions of garnets, tourmaline, etc., and it is an interesting fact that no trace of this latter mineral has been found in the Wainâd pegmatites (*cf. Coorg*). The country rock is usually a soft biotite-gneiss, in which mining should be easy and inexpensive.

References to some of these localities are incidentally made by R. Brough Smyth in his report on the gold mines of the Wainâd (pp. 6 and 37).

Salem.

Mica occurs as a constituent of the contemporaneous pegmatite veins which traverse the great granite intrusions forming the conspicuous *drûgs* in the south-west of the district and in the Erode valley. Plates of brownish muscovite, measuring a foot across the cleavage planes, were obtained by Mr. C. S. Middlemiss near Iddapadi, and a small amount of work has been attempted in the villages of Chinna-

malai and Arasiramani near Sankaridrúg.[1] The writer thinks, however, that it is not likely, judging by experience elsewhere, that the veins traversing granite will be found to contain mica in paying quantity: the proportion of large crystals is generally less and the veins more expensive to work.

Vizágapatám.

According to the District Manual (p. 155) mica occurs near Kodur in this district; but the kind and quantity are not given.

Specimens sent by M. M. Ry. M. V. Suryanarayana Rau, proprietor of the Waltair Estate, were examined by the writer and found to be phlogopite in even sheets, 4 to 5 inches in diameter. The peculiar properties of the mineral are referred to elsewhere (p. 23).

Permission to work mica has also been granted in the following districts of the Madras Presidency; but mining does not appear to have been so far profitable :—

Bellary district.—Rampuram in the Rayadrúg taluk.

Cuddapah district.—Polapolu in the Madanapalli taluk.

North Arcot district.—Gollapalli and neighbouring villages in the Chittoor taluk.

Trichinopoly district.—Shemmalai and Sigamkaradu in the Kulitalai taluk.

MYSORE.

The State of Mysore is composed entirely of crystalline and transition rocks, through which, at various places, pegmatites are intruded and occasionally carry mica of marketable quality. The most promising localities appear to be in the Mysore district, particularly in the neighbourhood of French Rocks, where clear muscovite sheets, 6 inches square, have been obtained; near Attikuppa and near Yelawal, where larger, but less valuable, mica-crystals have been found. The Hassan and Shimoga districts also contain deposits worth further prospecting, though they have so far yielded very little mica of value.

[1] Provisional Index, 1896, p. 16.

The State Geologist for Mysore has kindly furnished the following list of localities in which mica has been noticed, but apparently those already referred to above are the most promising:—

DISTRICT.	Taluk.	Village.
KOLAR	*Bagepalli*	Golapulli, Chokkampulli.
MYSORE	*Mysore*	Yelawal, Banmanahalli, Manikapura.
	Seringapotam	Vadesamudra, Settihalli, Kalenahalli, and other places near French Rocks.
	Mandya	Pallavanhalli, Chikkanahalli, Yaliyur.
	Nanjangud	Tayur, Tagadur.
	Heggadavankote	Three miles west of the capital town.
	Chamrajnagar	Begemalur.
	Malvalli	Ragimuddanahalli.
HASSAN	*Hassan*	Upper Hosahalli, Barudala Bore.
	Manjarabad	Kage Nere jungle and near the Hemavati river.
	Hole-Narsipur	Margonhalli and Halli Maisur.
	Arakalgud	Hardur.
SHIMOGA	*Chamageri*	Chikka Bennur, Soolekere tank.
	Nagar	Balekoppa, Mavinhole, cart-track to Palaguppa and Pingalegudda.
	Tirtahalli	Kathimaseyavahalli, Balehalli and 56th mile, Agumbe-Hariharpur road.
CHITALDROOG	*Holakere*	Visvanathanahalli.

PUNJAB.

Gurgaon.

According to Mr. Baden H. Powell,* a fine specimen of mica in large plates from Mahanti and Bhunsi in the Gurgaon district, Delhi

division, was exhibited at the Lahore Exhibition of 1864;[1] and Mr. F. C. Channing states that it is occasionally extracted near the latter locality.[2]

Bhábeh.

Plates of muscovite, 5 to 6 inches in diameter and 1 to 2 inches thick, of a brown colour, rarely silvery-white, were obtained by Mr. F. R. Mallet from granite veins near the Wangtu bridge on the Sutlej river.[3] Large plates of the mineral were sent to the Lahore Exhibition of 1864.[4]

Kúlú.

The contemporaneous veins in the gneissose granite and the pegmatitic veins traversing the associated schists in the Kúlú subdivision of the Kángra district are occasionally sufficiently coarse in grain to contain mica-crystals of marketable size; but the granitic formation, during or since its consolidation, has been deformed by earth-movements, and the mica-crystals have consequently been damaged. I have, however, seen plates from the Upper Chandra valley sufficiently free of flaws to give good plates five inches square. Quantities of small and damaged muscovite are raised in the granitised area around the Hamtá pass; but the material is used only as a non-conducting material for roofs and snow-cellars. Small plates of excellent muscovite occur in the upper reaches of the Parbatti valley; but for the reason that this area has been, in common with the rest of the Himalayas, folded in late Tertiary times, these localities are not likely to become profitable sources of mica. In any vein coarse enough to give large crystals, the proportion of waste material will always be excessive, and the area is, moreover, far from any market, being some 150 miles from the nearest station on the North Western Railway. Tourmaline and garnets are common accessories in the pegmatitic veins of Kúlú

[1] Punjab Products, Vol. I, p. 42.
[2] Settlement Report, Gurgaon District, 1882, p. 14.
[3] *Mem. Geol. Surv. Ind.*, Vol. V, 1864, p. 169.
[4] Baden Powell, Punjab Products, Vol. I, 1868, p. 42.

and Lahaul, and whilst the conditions for the *formation* of mica have been typically developed, the conditions for the *preservation* of large sheets are wanting: no area could more perfectly impress the fact that marketable mica requires an exceptional combination of special circumstances which can only be obtained within limited areas (*cf.* Introduction, p. 11).

RAJPUTANA.

Ajmere-Merwára.

Dr. R. H. Irvine says the mineral is abundant in the Ajmere district, where large plates can be extracted.[1] The latter statement is confirmed by the specimens recently sent by the Extra Assistant Conservator of Forests, who states that prospecting licences have been granted, but no extensive work so far carried out. The mineral is said to occur near Ajmere, Tilana and Bhinai in the Ajmere district, and at Rawatmal, Kalinjar, Suliakhera and Salupura in Merwára.

Jaipur.

A plate of muscovite measuring $10\frac{1}{2} \times 5\frac{1}{2}$ inches was sent to the Colonial and Indian Exhibition of 1886. The quality was, however, inferior to Hazáribágh mica, and the mineral does not appear to be raised for export.

Kishengarh.

Specimens of mica obtained from this State in 1898, and sent to the Imperial Institute by the Reporter on Economic Products to the Government of India, were considered by experts in the London market to be quite worthless, the chief defect being the striated and cracked condition of the sheets.[2] The specimens were not, however, intended to represent the best or even the average material obtainable in the State, but were mere surface specimens sent for a preliminary

[1] Irvine, Topography of Ajmere, 1841, p. 165.

[2] W. R. Dunstan, Agricultural Ledger, No. 2 of 1900, p. 20, and No. 24 of 1900, p. 229.

opinion, and an earlier answer without unnecessary publicity would have been obtained had the specimens been sent to the proper department in the first instance. An early opportunity was taken to depute an officer of the Geological Survey to examine the deposits, and Mr. E. Vredenburg has given a report of his inspection of the mica pegmatites and other minerals found in the Kishengarh State. He found numerous large veins of pegmatite traversing the gneissose formations, and many of them had been superficially broken in the search for mica; but the work was discontinued on account of misconceptions as to the mode of occurrence of the mineral. One of the most promising outcrops found was about a mile south-west of Dadia, and another, about a mile north of Neagaon, showed large mica-crystals in a pegmatite containing beryl. Mica of good size has also been obtained from pegmatites on the northern side of the road from Sarwar to Nasirabad, about two miles from Sarwar. So far, marketable material has not been obtained in quantity, but the veins have been only superficially examined, and the outcrops appear to warrant more thorough prospecting operations.

Tonk.

There are plates of muscovite in the Geological Museum, Calcutta, measuring 5 to 6 inches across and some of them are of fair quality. These have been obtained from several localities in the Chattarbhaj hills, north-east of Tonk.

Sirohi.

Major F. T. C. Hughes of the Errinpura Irregular Force reports the occurrence of mica near Rohera. Plates of good muscovite, 5 to 6 inches square, have been obtained. Major Hughes thinks there are indications of the same mineral in other parts of the Sirohi State.

V.—USES OF MICA.

A common question, and one which shows a justifiable curiosity, is occasioned by imperfect knowledge of the uses for which this peculiar mineral is purchased. As far as possible, I have gathered notes of the various ways in which mica is consumed in the Arts, but to an ingenious mind there must be numberless other ways in which some or all of its peculiar properties can be utilized. No other mineral, and no artificial substance, combines the natural properties of mica: its highly perfect cleavage, by which it can be split into the thinnest films; its transparency to light, combined with a comparative opacity to radiant heat rays; its imperfect powers of conducting electricity, giving it great value as an insulator; its chemical stability when exposed to the weather, or to corrosive oils and acids; the great flexibility of its folia, combined with a high elastic limit and consequent power to resist violent shocks or sudden changes of temperature, give mica a range of usefulness which is not likely to be imitated cheaply by any artificial substance.

The earliest use of the mineral was probably in the form of *window-panes*, as well as for *lanterns*, and mica was in consequence known as Muscovy glass (*Vitrium Muscoviticum*), which suggested the name *muscovite*, reserved in 1850 by the late Prof. J. D. Dana for the special variety which is by far the most abundant form so used. It was, however, subsequently replaced by the cheaper artificial substance, glass; but in the early stages of glass manufacture, when the processes for annealing plates had not been developed, mica was still retained for use in places where the window-pane would be subject to sudden shocks or violent vibrations, as, for example, on men-o'-war, where the shocks of heavy-gun firing shattered the badly annealed glass. Since, however, the processes for annealing glass have been developed to such perfection, and since it has been made possible to cast curved and variously shaped sheets of glass, it has entirely replaced mica for such purposes. In ordinary lanterns, too, mica has been replaced by

glass and horn; but as horn burns and glass cracks when exposed to a flame, mica is still retained to some extent for lantern uses.

As the transparency of mica is not affected by sudden exposure to heat, or by alternate heating and cooling, and as it is not readily attacked by vapours and gases, it is largely used in anthracite and gas *stoves*, from which a cheerful glow can be obtained if necessary, without exposure to direct heat. Its transparency for light, combined with opacity for radiant heat, creates for it a special usefulness as *fire-screens* in the peep-holes of furnaces, or as hand-screens in the laboratory and workshop for inspecting operations proceeding in highly-heated furnaces whose heat would otherwise be intolerable.

As *lamp-chimneys*, exposed to cold air draughts or rain-drop splashes, such as those outside drapers' show-windows in dangerous proximity to inflammable materials, or in the case of lamps giving out great heat, as in the case of the incandescent burners, mica is a convenient substitute for glass. Numbers of other uses for mica, depending on its non-inflammability and flexibility, have been devised; thus the electric cables for street installations are sometimes rolled around with mica films kept in place by tarred twine, whilst the Indian Mica Company have lately proposed to make *envelopes* of the mineral to preserve valuable documents from fire and insects.

By far the largest quantity of sheet mica is used for *electrical purposes*, for which the principal consumption obtains in America. Its highly insulating properties, combined with flexibility, indifference to sudden exposure to high temperatures, and the ease with which sheets can be cut to any shape, render it of great value in covering various portions of dynamos and other electrical machines. For similar and related uses, thin films, down to one-thousandth of an inch in thickness, have lately been used for making the so-called *micanite* in which the films are made to adhere to one another by a fusible and highly insulating cement. The relamination of mica in this artificial preparation is said to increase its insulating property. Plates of micanite when heated can be bent to any form to make, for instance, cylinders for armature shafts and cores, commutator shells and field-magnet cores.

It can also be rolled in thinner form as micanite cloth or paper for repairing transformers, armatures, etc., and in this form it is sold in rolls many feet long or in separate sheets cut to various sizes. The invention of micanite has created a new opening for the use of the smaller grades of mica formerly rejected as waste, and in India, where simple skilled labour is so cheap, the riving of thin films from waste heaps has lately given new life to many mines.

Thin sheets are used also where it is desirable to combine lightness with a certain amount of rigidity, as in the vanes of an *anemometer*, such as in Dickinson's or Biram's anemometer, used for testing the ventilation currents in mines. Similar sheets can be silvered for *mirrors* and reflectors bent to any required shape. They are also used for *lantern-slides* painted with transparent pigments; for covering photographs and pictures, and as a substitute for glass-plates and celluloid films in preparing photographic plates, from which the negative with a thin carrying film may be subsequently split. For mounting soft and collapsible natural history specimens for exhibition in spirit, thin sheets of mica are admirably adapted, and no convenient substitute can be found to remain unaffected by the spirit and at the same time transparent and soft enough to permit the free use of needle and thread for purposes of attachment. For the preparation of microscopic sections of small fossils, and for various optical purposes, the peculiar properties of mica give the mineral uses which are interesting, though of small value to the industry.

Besides the large sheets and plates, the smaller *waste scrap* and artificially *pulverised mica* have been turned to account in various ways. As an *electric insulator* it has been used to replace porcelain cups on telegraph poles. The chief use of ground mica depends on its non-conductivity for heat, and it consequently forms *non-conducting packings* and jackets for boilers and steam-pipes. For these purposes mica appears to combine advantages which render it superior to all other forms of laggings. The parallel disposition of the flakes increase its resistance to the passage of heat by conduction or radiation to a degree not possible in materials with fibres disposed in all directions.

It will stand any usual high temperature which would calcine hair-felt or other organic fibre, and will not disintegrate by vibration in the proximity of machinery; it is free from moisture and acids which would attack iron structures, and in the presence of moisture resists decomposition. Being soft at the same time, its accidental inclusion in a bearing would have none of the abrasive properties of, for instance slag or glass-wool. For non-conducting jackets, mica waste is now used on most of the railways in the United States and Canada.

Scrap mica in a similar way can be used as a protection against heat, a layer in the roof of a house, carriage or article of clothing forming a most effectual guard against the sun's heat in tropical climates, an appreciable relief being obtained by the use of a very thin layer. Mr. Mervyn Smith informs the writer that a layer of mica-waste, ¼-inch thick, placed under an ordinary tiled roof exposed to the hot-weather sun in Bengal, made an average difference of 15° in the temperature of the air immediately under the roof. The same device is of course correspondingly effectual in keeping in the heat during a cold weather night, and for a similar reason it may be used as a packing for ice-boxes or freezing machines.

Various other uses, besides ornamental, have been suggested for pulverised mica. It has been used, mixed with graphite or grease, as a *lubricant* for bearings working under heavy pressures; as a base for *soap*, and as an inert, absorbent medium, instead of infusorial earth, for taking up nitro-glycerine in the manufacture of a form of *dynamite*.

As far as India is concerned, the most extensive use of mica is for *decorative* and *ornamental purposes*, either alone or coloured, and in the form of plates, as well as in the pulverulent condition. Pliny refers to the employment of it, under the name *lapis specularis*, to produce a brilliant glistening effect on the arena of the ancient Roman amphitheatre, whilst in America quantities of the mineral have been found in the ancient graves of Indian tribes, by whom it appears to have been used for ornamental purposes, and its occurrence in some localities indicate a certain amount of commercial intercourse among widely separated tribes during prehistoric times.

In India it is used largely at native festivals, like the Mahommedan maharam, and at weddings, for processional ornaments as lamps and tinsel decorations on banners, *taziahs* and umbrellas. The powder is sprinkled on clothes, fans, wall-paper, toys and pottery, to produce a pleasing sparkle. Considerable quantities are used in sheet form for painting on in various parts of India, and pictures so painted for screen-making are obtainable in most large bazárs. A surprisingly large quantity of mica is used in India for these purposes and the industry is by no means new, for some of the mines have been worked for hundreds of years.

Mica has been tried, it is said, with favourable results as a *fertiliser;* but any virtues it possesses in this respect are probably due merely to its mechanical action on the soil, for it undergoes decomposition too slowly to affect the supply of available plant-food. Another use for the waste material has been tried by Mr. J. L. Spoor, of Messrs. Arbuthnot & Co., Madras, who about three years ago made some very satisfactory *fire-bricks* out of compressed mica-waste.

Finally, the native physician makes considerable use of mica in India for the preparation, in accordance with absurdly elaborate and intricate processes, of *medicines* for most diseases. An account of the principal use of the mineral in medical preparations is given in U. C. Dutt's *Materia Medica of the Hindus*, whilst Raja Sir Sourindro Mohan Tagore has enumerated a list of 224 medicines in which prepared mica is an essential constituent, and the same distinguished pandit has given a corresponding list of the diseases for which the medicines are supposed to be efficacious. One example in practical Hindu Materia Medica will be sufficient to show that the process of preparation is considered to be important. After an elaborate process for the preparation of dhānyābhra, or mica flour, Sir Sourindro Mohan Tagore gives the details of one amongst the several methods for its preparation for use in Hindu pharmacy as follows:—

"Pound talc with the following:—milk of the cow, the she-buffalo, and the she-goat; gangāpatra; man's urine; the offshoots of the *vata* tree; and the blood of the goat. Sublime a hundred times, when the talc, on being calcined, will assume the red colour of the ruby. Talc thus calcined when taken internally,

acts as a tonic, heightens the beauty of the complexion, strengthens the body, prevents untimely death, and removes the infirmities of age and all diseases."[1]

The Chinese also imagine that mica has certain virtues as a medicine. Although the effects obtained, or imagined to be obtained, in these cases, may be due to the substances administered with the mica, it certainly possesses one property which cannot be claimed for all medicines—it is perfectly inert and harmless.

Two sheets of transparent mica bent like a mediæval visor are used, suspended from the front of the head-dress, as a face guard whilst travelling on a fast motor car.

[1] *Abhra*, 1899, p. 5.

VI.—MINING PRACTICE.

(1) Underground and quarry work.

Two systems of mica-mining have been followed in India: in Nellore the mineral is raised in open quarries the slope of whose sides is determined by the angle of repose of the surrounding schists; in Bengal the mica is followed from crystal to crystal along tortuous, worm-like holes. The former practice is capable of improvement; the latter can best be improved by its abolition and the adoption of the rational methods employed elsewhere for mining ordinary lodes of known thickness, strike and hade. I am aware that the experience of the older workers in Bengal teaches them to favour the old native methods which have been followed for centuries. Till recent years, with an abundance of pegmatite-veins exposed, and with little competition, the old method may have been good enough. But it must be remembered that the practice of the past has been merely a process of "picking the eyes out" of the country, a practice satisfactory enough when the supplies of the mineral are more than sufficient to meet the demand, and when very little capital is available for more systematic operations. But now most of the promising pegmatites have been picked near the surface, and there is greater competition for the few mines available, it is by no means too early to regulate the extravagant and casual way in which the work is generally performed. However, these matters can best be discussed when the mining methods now practised are described, and we will commence first with Bengal, where mining has been carried on for so many years.

Bengal.—Capt. W. S. Sherwill gave the subjoined account of the method of mica mining followed by the natives in 1857:—

"A small and convenient hill having been chosen as the spot for commencing operations upon, a party of the wild hill tribes, named Bandathis, the members of which party have freely propitiated the local tutelary god or goddess, both by sacrifice and by getting very drunk, ascend to the top of the hill and commence sinking a series of pits, the whole way down the profile of the hill, about three feet in diameter each, and a few feet apart. These pits are not continued vertically

downwards, but in a zig-zag shape, but nevertheless not so much out of the vertical proper, as that a basket containing the mineral cannot be hauled up from the bottom of the pit to the top; the zig-zag shape of the shaft being formed by sinking the shaft first inclining to the left a few feet and then to the right a few feet, the head of each cut or notch forming a landing-place or step, and thus the necessity of ladders is obviated; the projecting of salient angles of the notches forming a perfect flight of steps from the top to the bottom of the pits, which seldom reaches to a greater depth than forty feet when, darkness interfering with the workman's progress, the pit is forsaken and another commenced upon a few feet further down the hill. A slight framework of faggots, cut from the neighbouring trees, is placed over the mouth of each pit, upon which a man sits, waiting till the signal from below is given to haul up the basket containing the mica and rubbish, which has been dug from the sides of the pit by the aid of a rude pick. On arrival at the surface the good and bad materials are separated; the earth and rubbish are shot down the precipitous side of the hill."

Under European management the methods of mining have not greatly improved on this plan. The mica is followed from one "book" to another, and only as much material excavated as is necessary for working room, the mines are consequently developed into long meandering holes, sometimes down to a depth of 300 feet. The whole of the materials—mica, rubbish and water—are brought by a string of coolies up to the mouth of the hole, which is often near the summit of a hill, being the point where, by reason of better exposure, the pegmatite outcrop was originally discovered. On account of the accumulation of water, all mining operations are suspended during the monsoon season, and at the close of the rains the process of "forking" a mine occupies several days and sometimes weeks. In the same way, an hour every morning is spent in baling out the water accumulated over night. With the one exception now being inaugurated at Bendi, there is not a single vertical shaft in the whole mica-mining area of Bengal, not a single drive or cross-cut to show that the miners have appreciated the actual disposition of the pegmatite as normal intrusive sheets, and, notwithstanding the favourably-shaped natural contours of the ground, not a single adit for the removal of water. That mica-mining has yielded large profits under such remarkable circumstances affords strong presumptive evidence of the value of the deposits, and of the success which should be expected to follow a more scientific

working of the many fine pegmatite sheets hitherto undeveloped.

The means adopted for ensuring the safety of the mines are, as a rule, most prefunctory, whilst no special effort whatever is made to ventilate the deep, narrow holes in which the miners are crowded, smoky oil-lamps used and explosives largely employed. Whilst present at a mine extended to just 300 feet below the surface, I witnessed the discharge of 25 holes charged with dynamite: the blasts went off in salvoes of twos and threes, and, after a slight discussion at the pit's mouth as to the number of successful fires, the miners streamed into the pit, whilst the fumes and dust from the explosions floated out at the mouth, and ventilation was allowed to proceed by simple diffusion. To a certain extent the ventilation difficulty cures itself by the cessation of work at nights; but the fact that I found it impossible, on account of the haze of smoke and dust, to obtain a photograph, even in strong magnesium light, at a depth of 110 feet in one of the mines, shows that the ventilation is not above reproach within two hours after the commencement of the day's work.

In order to reduce the fouling of the air in the mines to a minimum, blasting is generally performed as the last operation in the evening, and the mines are then left for the night. As a consequence of this practice, much of the mica thus freshly exposed is stolen in the night, and the owners have to pay in another way for the false economy of neglecting the recognised principles of mining.

Notwithstanding the definite regulations framed by the Local Government, there was not a single plan of any of the mines in existence when I visited the district in 1898, and the managers knew only in a general way of the positions of the works and miners under ground. The enforcement of this regulation is not only important to meet the questions which might arise in case of accident or trespass, but if plans were regularly made the managers would be able to direct the work in a much more economical and intelligent way than is done at present. A case in the Koderma area will illustrate this point:—A

mine was opened near the summit (C, fig. 17) of a steep-sided, roughly

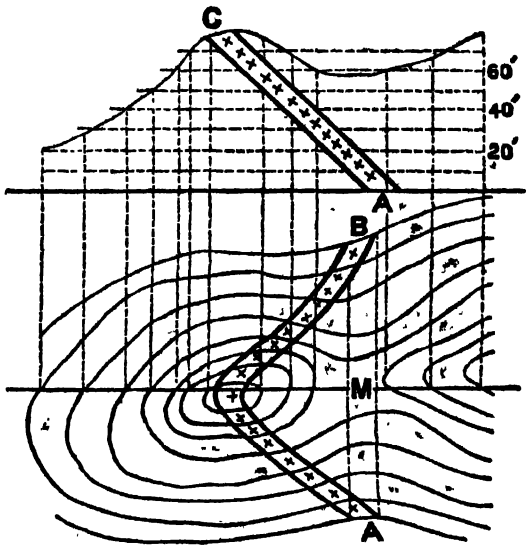


FIG. 17. *Plan of hill showing the outcrop of a pegmatite-sheet, and section of the same in the direction of dip. Scale, 1 inch=100 feet.*

conical hill, and followed as a slightly tortuous hole for 115 feet at an angle of 45°, almost exactly in the direction of true dip of the schists and that of the included pegmatite-sheet. The pegmatite was originally discovered at the summit of the hill because it had been laid bare by weathering, and it never occurred to the manager of the mine that the same sheet stretched obliquely through the hill with a continuous outcrop on either side, merely hidden by the thin layer of loose rubbish and vegetation (fig. 17). The whole of the materials—mica, rubbish and water—were handed up by a string of 80 cooly women to the mouth of the pit (C), whereas for a very small fraction of the working expense, the pegmatite vein might have been attacked on the flanks of the hill, the materials brought out by trams along gently sloping drives (A. M. and B.M., fig. 17) and the drainage problem allowed to settle itself by natural flow of the water along the same adit.

The saving effected would not be due merely to reduction of labour. The miners, working blindly at the bottom of a cœcal hole, damage large quantities of mica, more, very much more, than the manager appeared to suspect, whilst by tackling the pegmatite-sheet with systematic over-hand stoping from the adit described, such damage to the mica "books" would be reduced to a minimum. Fig. 17 is a plan of the hill showing how the position of the outcrop of the pegmatite might have been traced with merely the knowledge of its angle of dip and the position of the outcrop at the summit *C*. As at present worked the whole of the materials are brought out of the opening at *C*, whilst mining is going on at a point below ground corresponding to *M* in the plan. The instance referred to is a mine where by chance the contrast between the actual practice and the ideal method is unusually pronounced, and the surface features are not always so convenient for making a drive without the preliminary expense of a vertical shaft and cross-cut. In a level country such operations would of course necessitate the outlay of capital, with the attendant risk of the pegmatite proving less remunerative than indicated by the preliminary prospecting operations. Such a risk can, as a rule, be borne only by a company, whilst hitherto mica-mining in Bengal has been undertaken by individuals with, from a mining point of view, very limited resources. At present a mine is only continued as long as it pays from month to month, and this expensive system is preferred to the risks of a more complete organization. As already stated, such a system of work is satisfactory as long as there is an abundance of material near the surface, little competition for land, no capital available, and the miner ignorant of the structural characters of the pegmatite-sheets. But the time for the casual native method is past, and an economical system should be insisted on for the good of the mine-owners, as well as for the purpose of making the most of the natural resources of the country, which, as explained on an earlier page (p. 11), are necessarily limited.

Nellore.—The system of working mica in wide, open quarries, as practised in the Nellore district, suggested itself on account of the level nature of the surface, and the occurrence of the pegmatite in large

lenses and stocks. The system was adopted by Mr. E. H. Sargent at Inikúrti, the first mine successfully worked, and the success attending Mr. Sargent's work has led to imitators in other plots where the conditions are less favourable. Inikúrti, however, is a most exceptional instance, the pegmatite stock being some 300 feet long and 150 feet wide, with the quartz forming a large boss in the centre and the mica and felspar disposed in a horse-shoe shaped zone around (fig. 18).

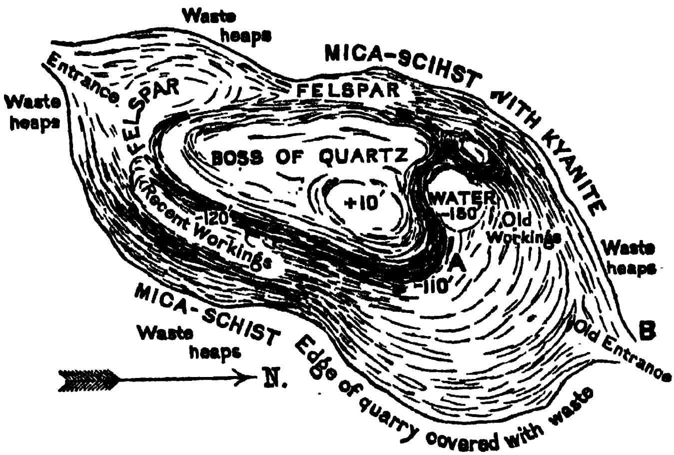


FIG. 18. *Plan of the Inikúrti quarry, December 1898.*
Scale, 1 inch = 100 feet.
Levels, + above, and — below, the surface of the plain.

Nevertheless, Inikúrti is now reaching a stage where the expense of working is gradually encroaching on the revenue obtained from the mica raised; for the sides of the open quarry, with the large masses of waste piled around, are slipping back into the quarry as fast as the bottom is being lowered, and the system which has allowed a sufficient margin of profit in the past will have to be substituted for a more rational organization in the future.

With a wide open quarry already made, the adoption of a system of shafts, cross-cuts and drives may be found inconvenient, and the sides of the quarry having extended back, in practically such cases, by falling in during work, there will always be considerable trouble

from falls of decomposed rock during the rainy season, a source of expense which will continue, and become an increasing charge, as long as simple open quarrying is continued and the sides allowed to remain raw. In cases where there is a marked inclination in the dip of the pegmatite-sheet, it will be more economical in the long run to sink a shaft near the side of the quarry and reach the pegmatite by a cross-cut, or, where the dip is not far from the vertical, the shaft should be placed along the line of strike and the pegmatite worked along drives with over hand stoping in all cases.

The practice of sinking on the pegmatite—pursued both in the Bengal worm-like mines and in the Nellore quarries—is giving rise to a shocking destruction of good mica: a single blow with a pick, or a hole bored for blasting through a mica "book" an inch thick, may result in the loss of many rupees. It must be remembered that a "book" of mica only one inch thick and six inches square weighs over 3½ lbs. and may be worth Rs. 15 to Rs. 20. A hole through the centre of such a bundle would reduce its value to less than as many annas, and the writer has seen many instances where such damage has been done. Presumably every reasonable care is taken in the use of the pick and in drilling holes; but the present system of sinking on the pegmatite in which the mica is concealed by the inevitable rubbish, always wet, places the miner at a great disadvantage. With overhand stoping the miner is able to keep a clean and dry working face, on which the indications of a "book" are readily detected, and the mineral removed without damage. But in addition to this more careful treatment of the valuable mineral itself, there is a saving in necessary dead-work; for in blasting out the loose-textured pegmatite, the explosive is assisted by gravity; the waste material is more than sufficient for stowing the worked-out excavations, thus saving the cost of its haulage to surface and removing the necessity of permanent timbering in the winzes and rises; the work can also proceed continuously instead of being interrupted by a luxurious cessation at nights and during the monsoon, for water does not accumulate on the working face of a rise. Even, however, if overhand stoping were adopted, the

destruction of mica through ignorance and carelessness will only be reduced to a minimum when a system of contracts, like the "tribute" and "tutwork" in Cornish mines, or the system of "bargains" of the Welsh slate quarries, is adopted.

In the few Nellore mines where open quarrying is still possible, a considerable saving might be effected, notwithstanding the cheapness of labour, by simple machinery like the "Blondin" hauler of the Scotch stone quarries, and by using pumps or pulsometers for the removal of water. In opening new mines, however, it would be far more economical in the long run if the ordinary vertical shaft arrangements were adopted after the value of the pegmatite-vein has been tested by surface-working along its outcrop. Inikúrti has given rise to the idea that the pegmatites of Nellore form stock-like masses, irregular in shape and having no determinable disposition in the schists, whereas Inikúrti is an exceptional case; the lenticular masses are usually much flatter than this and are often best described as sheets with a strike and dip of fair constancy. Even Inikúrti might have been worked for a small fraction of what it has cost if, after its richness had been proved beyond question in 1891, a properly organized system of mining had been adopted by the judicious outlay of a little capital with underground instead of open workings. It must be remembered that the advice offered above by no means covers the whole art of mica mining. Every occurrence has its peculiarity, and requires, consequently, a special form of attack, and the most economical system of working will consist of a judicious selection from the great variety of recognised mining practices, modified, if necessary, by the ingenuity and common sense of the manager to suit the special local conditions.

There is still another form of economy which would be more easily accomplished if the mines were worked as larger concerns, and that is in the transport of the mica from the mines to the godowns. At present the mica is carried by coolies, and, besides the expense of mere transport, the practice affords an opportunity for theft, the general prevalence of which is shown by the existence in some centres of mica "producers" who possess mines from which mica, any expert

knows, can only be extracted by miraculous means. This source of loss, and saving in transport, might be met by the employment of wire-rope tramways; but their use is hardly possible when there are so many petty miners working a very limited area. Large trusts have their evils, and in another direction complete isolation of interests has its drawbacks also. A certain amount of combination is absolutely necessary in some forms of mining, for which the smallest amount of capital possible for economical working generally exceeds that which an individual can afford to risk. With only one exception to my knowledge, the mica-mine owners in India are not able, or at least have considered it undesirable, to pay for a properly qualified mine manager, one reason being the smallness of the "venture." As a result, they are paying in many cases at least twice as much as they need do in mining expenses: there is an absence of system in attacking the deposits underground, due to ignorance of the geological conditions under which mica occurs, and a serious waste in surface management, due to ill-acquaintance with the methods which sharp competition has occasioned in more highly developed mining countries. Like all other forms of mining, mica has its crop of sad failures; but there is probably no other mineral which lends itself more to reduction of risks in the hands of the trained miner, and no other which more quickly brings the usual reward of false economy. Nevertheless, the fault is not entirely with the "adventurer," for the rules which have hitherto been in force permitted a maximum mining lease of five years only, a period barely sufficient for the development of the preliminary shafts and cross-cuts, and consequently utterly insufficient to obtain returns proportionate to the capital necessary for regular mining operations. However, it is hoped that these limitations, and the more serious insecurity of tenure, will shortly be removed as far as is consistent with other important interests.

The native system of mining naturally gives quicker returns, and has the advantage of requiring a small outlay of capital; but the mine worked by the native method has a total life (measured by output, not years) little longer than what would be considered

merely the exploratory stage of a mine opened by recognised mining methods, and the latter (working a deposit of similar richness) will commence an indefinite period of steady and uniform returns when the former has reached its limit of remuneration. A single instance will neither completely confirm, nor will it disprove, this statement; for no form of mining is without its risks, either of unexpected variation in the mineral deposits, or of unforeseen errors in management. But those concerned in the mica-mining industry will nevertheless watch with interest the result of the operations now being undertaken by the Indian Mica Company, which is laying out capital under the advice and management of Mr. A. Mervyn Smith near Bendi in the Hazáribágh district, where they have departed from the old local custom, and are opening out a pegmatite-vein by systematic development of drives from vertical shafts. The work has scarcely as yet passed the exploratory stage, and the relations between the expenditure and returns are consequently not uniform; but the results so far obtained will nevertheless be instructive to other mica miners. The following details are extracted from a note by the manager, Mr. A. Mervyn Smith, who has, with the consent of his Directors, kindly given me all the information at his disposal:—

The vein now being worked at Lalki, near Bendi, has a strike of north-west - south-east and an average underlie of 45° E. to north-east. It cuts obliquely through the mica-schists of the country, and, as is generally the case with pegmatites which do not conform to the foliation-planes of the surrounding schists, it varies considerably in thickness, shape and direction, showing a tendency also to send off numerous apophyses. The underground workings, which do not go beyond a depth of 102 feet, communicate with the surface by three vertical shafts, and an incline of 1 in 6. Although carefully timbered and provided with proper ladder ways, the coolies objected to the vertical shafts, and the incline was primarily made as a concession to their prejudices; but it has also been found to be otherwise very useful. It is now provided with a tramway, served with a hauling engine and 3-feet twin drums, by which the excess of rubbish, not used for stowing in the mine, is brought to the surface. A double, 4½-inch, ram, Cameron pump keeps the mine dry at ordinary times, its work being supplemented during the rainy season by a self-filling water-truck run along the incline. Altogether 1,533 feet of drives and cross-cuts had been made up to July 1901. Last year's work cost R13,740 and included, in drivages and sinking, a total of 916 feet, which works out to the extremely low rate of R15 per foot, covering all except London charges. The material excavated in the overhand stopes is mined and removed to

the surface at a cost of something less than 8 annas a ton. Common country-made gunpowder is found to be sufficiently effective in the stopes, and, being also much cheaper, is preferred to dynamite. An estimate made from the results of the last quarter's work shows a yield at the rate of 40lbs. of rough, or 10 lbs. of dressed mica, per ton of pegmatite stoped. The dressed mica was valued at an average price of 12 annas a pound; so each ton of pegmatite mined yielded dressed mica worth R7-8 *plus* waste worth about R1-14, a total of R9-6 per ton. The general characters of the pegmatite-vein being worked are now well established for a length of over 300 feet, showing an average thickness of 40 feet, with mica noticeably concentrated towards its selvages. It was formerly worked by natives who mined only on the foot-wall margin, as the much richer deposits, now proved by cross-cuts to occur near the hanging wall, were not noticed by them on account of this edge of the surface-outcrop being concealed by the overburden.

This last statement is the only one on which the writer feels at present free to offer comment. It illustrates the contention, iterated in preceding paragraphs, that the native method of mining does not turn the natural resources of the ground to full account, and, from the Government's point of view, this, in view of what we know of the limited nature of our mica resources, is a serious consideration. The owner of mineral rights, whether a Zemindar, Jaghirdar or the Government, naturally wishes to make the most of the minerals available, and the writer contends that the native method of mining not only results in the destruction of much good mica within reach, but is incapable of exploiting and working out the full resources of a pegmatite-vein. The principles of mining formulated in more highly developed countries are the result of sharp competition and experience; their proper observance consequently permits a lower average working charge at shallow depths, and, therefore, of profitable operations to greater depths. There is, of course, a judicious medium in this as in all things, and whilst the present system is pernicious and wasteful in one direction, the writer would like to add to this advocacy of better organization, a warning against over-capitalizing a small industry, and against the danger of swamping a small market by large output. The latter, however, is a danger which ultimately brings its own cure, for a reduction in prices by abundance of supply will tend to suggest new uses for the mineral.

(2) Dressing.

The practice of splitting the "books" and dressing the mica sheets at the surface does not lend itself to the criticism which I have been forced to make with regard to the underground work. In Bengal the sheets are merely sickle-dressed by trimming off the broken and flawed edges by obliquely directed cuts with a large knife or sickle. The dressed sheets are left quite irregular in shape, and in this form are sent to the London market. A similar practice is adopted in many of the Nellore mines, and many of the managers stated that they have been instructed by London agents to supply the mica in these irregular pieces rather than in rectangles. Mr. E. H. Sargent, however, on opening the Inikúrti mines, instituted a practice of sending mica to the market only in the form of the largest possible rectangle, and he claimed that the system was more profitable. Rectangles are utilized with less waste than irregular sheets of the same grade, and they consequently bring a higher price, besides being more convenient to pack for safe carriage, and requiring less freight. The writer was formerly inclined to favour the system of cutting perfect rectangles before placing the mica on the market; but the advantage is probably not so great since mica of various shapes is required and the trimmings can be turned to account. There is now, however, another and much more important reason for sending mica to the *general* market in the roughly-trimmed (sickle-dressed) condition, and that is the outcome of a recent change in the import tariff of our largest customer, the United States. According to the Dingley Tariff Act, which came into force on July 24th 1897, mica imported into the United States was classified into (1) "unmanufactured," and (2) "cut or trimmed," the former class including the roughly cleaned or "thumb-trimmed" mica, as they call it in Canada. Both kinds are taxed with an *ad valorem* duty of 20 per cent.; but, whilst the "unmanufactured" material is charged with an additional 6 cents per lb., the "cut" mica is taxed with an extra 12 cents a pound. The effect of this law soon made itself manifest in a very natural way on the trade, not decreasing the total import, but

completely changing the nature of the imported material: the lower grades became shut out by the prohibitive tariff, and, at the same time, amongst the higher grades roughly trimmed naturally became preferred to cut mica, the latter being imported to the States only when wanted for special purposes, and then bringing, of course, a special price of which the poundage forms a small fraction. The working of this law gave new life to many old mines in the States, the domestic production rising at once from 17,630 lbs. in 1896 to 118, 852 lbs. in 1897. At the same time, the tariff caused a severe shock to those mines in India which produced only second-rate material. There is, of course, a comparatively small demand for rectangular cut mica outside the United States, and English consumers naturally wish to see the market flooded with such material, not because they want rectangles only, but because the preparation of the mica in this form makes it, on account of the peculiar working of the Dingley tariff, less acceptable to American buyers whose competition is thus avoided. Of the sheet mica imported by the United States in 1900, that classed as "unmanufactured" amounted to 1,892,000 lbs., whilst the "cut or trimmed" mica reached only 64,391 lbs.

In the preparation of rectangles the mica sheets are, after the preliminary drying, splitting and cleaning, "scribed" with the help of

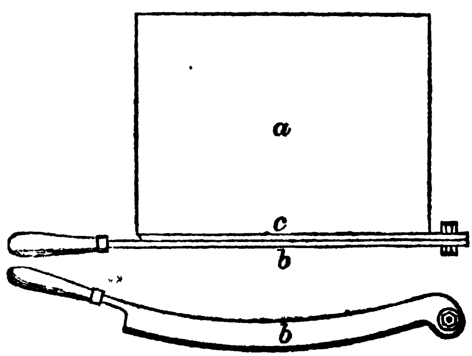


FIG. 19. *Table with knife for cutting large sheets of mica. Scale, 1 inch=2 feet.*

patterns of sheet zinc, tin or iron, to include the largest possible area of good mica; they are then cut along the ruled lines with a pair of ordinary garden shears, one handle of which is fixed to a log of wood in the ground with the cutting plane vertical (see plate I). A special form of cutting table is used for large thick sheets, too heavy for the shears. The table, 2 to 3 feet square (see plate I and figs. 19 and 20) is made of a 2 to 3-inch block of teak-wood, supported on firm legs and faced with a half-inch plate of steel (*c*), with the upper border made slightly acute to act as a cutting edge against the long, curved knife (*b*), also about half an inch thick, and hinged against the steel plate at the corner of the table.

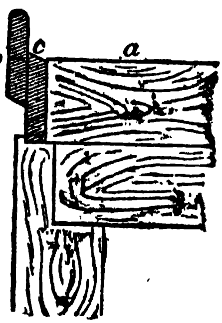


FIG. 20. *Section through the cutting edge of table shown in Fig. 19. Scale, one-fifth.*

An important part of the dressing operations consists of splitting the mica to remove damaged films or inclusions of foreign minerals which would, if allowed to remain, reduce the market value of the whole sheet, the slight loss of weight so incurred being more than compensated for by the higher price obtained for the residue. It is this part of the dressing which requires most judgment, and it is the part too often neglected by the managers, who do not fully appreciate its value.

(3) Quality and Price.

The mica sent to the market from India is practically all muscovite, which varies greatly in colour. The characteristic and favourite

material raised in Bengal has a ruby-tint, a deep ruby-colour being the common intensity of the light transmitted through "books" half an inch thick. A greenish tinge more often characterizes the Nellore mica, but other colours are also found—smoky brown, pale amber, bright olive-green, and, more rarely, a bleached mica with silvery lustre. Formerly only transparent mica, free of stains, found a sale; but the objection to the presence of the well-known brown and black, iron-oxide, interlaminar inclusions only holds for a limited portion of the uses to which the mica is put, and such material now brings a good price as long as it conforms to the desirable standard in toughness, cleavage, elasticity, freedom from pressure-figure flaws and evenness of surface.

With mica of the same quality, the price varies with the size of the sheets, according to which the product is graded. The grades are not, however, absolutely fixed, but the following list represents the usual grading :—

Specials,	over 36	square inches.
No. 1	24 to 36	
No 2	15 ,, 24	
No. 3	10 ,, 15	
No. 4	6 ,, 10	
No. 5	3 ,, 6	

The maximum rectangle obtainable from any sheet of irregular shape is readily determined by placing it on a plate ruled into inch squares, the squares being numbered along the direction of the two co-ordinates from the left-hand lower corner. In addition to size, shape has an influence on the market price; amongst samples of mica of the same superficial area, long strips are in greater demand than square sheets, whilst pieces cut to a specially required shape naturally bring a special price, as they entail no waste.

When Mr. Mallet visited the Behar mines in 1873, the native miners recognised a series of grades, to which they gave the following special names :—

Karra,	about 50 to	100	square inches.
Rási,	,, 30 ,,	50	,,
Manjhla,	,, 20 ,,	30	,,
Sanjhla	,, 12 ,,	20	,,

Besides these, specially large sheets were distinguished as *admalla* and *urtha*; but the sizes appeared to vary at different mining centres. The writer was informed by Mr. W. H. Paschoud, Manager of the Singho division of Messrs. Chrestien & Co.'s mines, that the native miners still employ the terms *manjhla* and *sanjhla* for intermediate sizes, the ordinary adjective *bara* being used without special limitations for large specimens, whilst the smaller grades were merely known as *chhota*, and the waste, *raddi*.

Prices are extremely variable, and the market, being a comparatively small one, is sometimes subject to considerable artificial variations according to the wishes of the larger producers. The following quotations from recent sale reports of the Indian Mica Company will, however, give an approximate idea of the value of the mineral.

Report of a recent sale of sickle-dressed mica in Calcutta.

	Clear ruby.	Stained ruby.	
No. 1	Rs. 305	Rs. 185	per maund of 80 lbs.
" 2	" 190	" 85	" "
" 3	" 82	" 43½	" "
" 4	" 36	" 24	" "
" 5	" ...	" 10	" "

Special sale of small lots.

8″ × 8″,	Clear ruby,	18*s.*	per lb.
8″ × 8″,	Stained ruby,	13*s.* 6*d.*	"
6″ × 6″,	Clear ruby,	12*s.*	"
6″ × 6″,	Stained ruby,	9*s.* 6*d.*	"

Scrap mica.

No. 1 quality (used for boiler and pipe-coverings) 13*s.* per cwt.
No. 2 " (used for covering roofs) . . 7*s.* "

Recent London valuations of a consignment of stained, sickle-dressed, ruby mica.

Special.	3*s.* 6*d.*	to	4*s.* 6*d.*	per
No. 1	2*s.* 6*d.*	"	3*s.* 6*d.*	,
" 2	1*s.* 3*d.*	"	1*s.* 9*d.*	,
" 3	9*d.*	"	10*d.*	,
" 4	4½*d.*	"	5½*d.*	,
" 5	2*d.*	"	2½*d.*	,

These prices are much lower than those which have been obtained for clear ruby mica of the best quality, of which the price varies too greatly to give a fair average. The lumping together of sheet mica with scrap prevents the use of export statistics as a test of the average value of sheet mica sent out of India; but in the tables of production for the United States the two kinds are estimated separately, and the following table gives the average value of sheet mica produced from 1893 to 1898. These are values estimated at the place of production, but they are in the country where most of the mica is consumed, and to compete with the American producer, the Indian miner must be able to meet his extra charges connected with freight and duty.

Production of sheet mica in the United States.

YEAR.	Quantity in lbs.	Value.	Average price per lb.
1893	6,500	£ 1,195	3*s*. 10*d*.
1894	9,900	£ 2,220	4*s*. 7*d*.
1895	6,200	£ 1,280	4*s*. 3*d*.
1896	17,630	£ 2,506	3*s*. 0*d*.
1897	118,852	£ 16,659	2*s*. 11*d*.
1898	110,928	£ 18,446	3*s*. 5*d*.
1899	97,586	£ 15,385	3*s*. 2*d*.
1900	127,241	£ 16,502	2*s*. 7*d*.

Scrap mica in the United States brings from 30*s*. to £ 2 a ton.

(4) Labour.

In both the principal mica-mining areas, Behar and Nellore, labour is fairly plentiful and cheap. In the Behar mines, Sonthals, Kols and other Kolarian tribes are employed, and the men earn from two to two and a half annas for a working day of eight hours, the women and

children earning less. The number of coolies employed naturally varies according to the size of the mine, but they seldom exceed two hundred and fifty and the number in constant employment in the district is about five thousand.

In Nellore the miners are principally pariahs with a few of the shepherd caste earning slightly higher wages than those working in the Behar mines.

(5) Production and Trade.

During the year 1900 there were 131 mines, employing 9,517 persons at work on mica. The total outturn amounted to 916 tons, slightly more than half of this amount being raised in the Nellore district which is now outstripping Bengal in the development of its mica resources. The returns for previous years are shown in the table below; but there is no doubt that, on account of the large production in zemindaris, the figures are quite incomplete. In fact, the import returns of other countries are in excess of these quantities.

	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.
Quantity in tons.										
Bengal	209	93	120	190	180	376	311	445	267	356
Burma				...	...	1½	...	...	5¼	
Madras	100	137		4	3	23	22	246	151	262
Mysore				2	2½	3	2	2¾	2½	2½
Value.										
	£	£	£	£	£	£	£	£	£	£
Bengal . . .	9,734	5,800	6,543	10,013	9,692	21,107	22,831	13,267	15,004	20,466
Burma . . .	2	...	[illegible]	...	...	11	...	...	18	...
Madras . . .	76	430	...	500	460	3,360	3,270	81,342	37,350	40,153
Mysore . . .	...	...	...	11	12	16	9	14	13	14

By far the largest quantity of Indian mica is sent to the United Kingdom which, however, is a market also for American buyers. Smaller quantities are sent direct to the United States, Germany and France, whilst casual shipments have been made at different times to the Straits, China, Austria, Mauritius and Natal. The only other countries which can be regarded at present as competing with India in the production of mica are the United States, which consumes the whole of its own production, Canada, which exports largely to the United States, besides consuming a portion of its own material, Argentina, Australia and Ceylon. Small quantities, mainly of scrap mica, have at times been raised in England, Norway, Russia and a few other countries; but India controls the market for the higher grades. The imports of sheet mica into the United Kingdom have been gradually rising during the past few years to the value £142, 371 in 1898. The estimated value of the mineral imported into the United States rose from £25,237 worth in 1894 to £30,020 in 1898, followed by a sudden rise to £55,185 in 1899 and to £63,912 in 1900. Of these amounts, Canada, which comes next to India as a producer, contributed mica worth £5,310 in 1894, £13,902 in 1898, with a jump to £29,648 in 1899. Canada may possibly be the origin of half the mica entering the United States, but the remainder, and most of that consumed in the United Kingdom, comes from India. Nevertheless, the mica-mining industry of Canada is making great strides, and its phlogopite is seriously competing with the muscovite of India.

(6)—Mica Mining Rules.

MADRAS.*

Prospecting.

1. *Applications.*—Licenses to prospect for mica in the classes of lands specified in paragraph 3 of Board's Standing Order No. 15 (of which the principal are reserved forests, reserved lands and unreserv-

* Government Order No. 125, Revenue, 13th February 1900.

ed lands at the disposal of Government) will be issued by the Collector to whom applications should be addressed.

In the case of the lands specified in clauses (*a*), (*b*) and (*c*) of paragraph 3 of the Standing Order, the prospector should make his own arrangements with the occupants of the land for the acquisition of the surface rights.

2. Each application should bear a court-fee stamp of annas 8 and be accompanied by a certificate of approval of Government under sections 10 and 11 (3) of the Government of India mining rules, and should contain the following particulars:—

(*a*) The name, residence and profession of the applicant.

(*b*) A description as accurate as possible, and illustrated by a sketch prepared to scale, of the situation, boundaries and area of the land with respect to which the licensee is required. The position of the plot required must be determined in the sketch with reference to known points.

3. *Period of License.*—The term for which the license shall be granted shall be one year or such shorter term as the applicant may desire. The license may be renewed by the Collector for a further term not exceeding two years whenever he is satisfied that the licensee has been prevented from completing his search of the land by any cause other than his own default.

4. *Fees.*—A surface rent equal to the land assessment in the case of all classified and assessed lands, and in other cases to the rate at which corresponding lands in the neighbourhood are assessed for land revenue, shall be paid for the land covered by the license, provided that the total rent levied annually under this clause on the lands covered by the license does not exceed the average rate of one rupee per acre.

5. The licensee will be allowed to remove free 1 cwt. of mica from the land covered by his license, and on all quantity removed in excess thereof a royalty of 5 per cent. *ad valorem* shall be levied.

6. *Size of Blocks, etc.*—A prospecting license will be restricted to such area as is reasonably required for *bonâ fide* prospecting purposes, the minimum extent being 10 acres. In determining the area to be granted the Collector will have regard to the means at the disposal of the prospector, but in cases in which the area to be granted exceeds 1 square mile, the Collector will make a reference to the Board before issuing the license.

Grants of licenses made by the Collector will be reported to Government through the Board of Revenue. Licenses are liable to be cancelled by the Board or Government if, on appeal from any of

the parties affected by the Collector's order or otherwise, such a course is found necessary.

7. *Deposits.*—No application for the grant of a mica-mining lease will be taken into consideration unless the applicant deposits as security in respect of each lease such sum as the Collector may determine or gives security to the like amount to the satisfaction of the Collector, the maximum deposit in any case being Rs. 500. The security deposit will not be refunded until the licensee has, on the expiration or resignation of his license, filled in all pits excavated by him to the satisfaction of the Collector, and if he fails to do this himself within 6 months the work will be done at his expense. Should the licensee convert his prospecting license into a mining lease the deposit will, subject to such deduction as the Collector may order on account of damage done to the land, be credited as a mining deposit under paragraph 19.

8. No licensee shall cut or injure any tree on unoccupied and unreserved land or reserved forests without the permission of the Collector in writing. But it will be open to him to acquire any such trees at prices fixed by the Collector.

9. Neither the licensee nor any one claiming through or under him shall assign the license or transfer any right or interest thereunder without the previous consent in writing of the Local Government.

10. In case of any breach on the part of the licensee of any of the conditions of the license the Collector may summarily revoke the license and thereupon all rights conferred thereby or enjoyed thereunder shall cease.

Mining.

11. *Applications.*—Applications for the grant of mining leases in the classes of land specified in paragraph 3 of Board's Standing Order No. 15 should be presented to the Collector who will, if he sees no objection to granting them, submit them through the Board of Revenue for the orders of Government. In the case of lands specified in clauses (*a*), (*b*) and (*c*) of paragraph 3 of the Standing Order, the applicant should make his own arrangement with the occupants of the lands for the acquisition of surface rights.

12. Each application should bear a court-fee stamp of 8 annas and contain—

(*a*) the name, residence and profession of the applicant;

(*b*) a map of the area over which the proposed lease is to extend. The map should be prepared to scale and the position of the plot determined with reference to known points.

13. *Period of Lease.*—The maximum term for which a mining lease will be granted is 30 years.

14. *Fees—(i)Royalty.*—A royalty of 5 per cent. *ad valorem* shall be charged on all mica removed from any mine. Estimates of the value of mica, according to the size of the plates in which it is removed, will be framed from time to time, and each lessee shall be liable to pay the amount of royalty due as calculated on the assumption that all the mica removed from his mine is the best of its size and will fetch the estimated value; if any lessee prefers to defer payment of royalty until the actual sale price is known, he will be allowed to do so on furnishing a deposit sufficient to cover the amount of royalty payable at the schedule rates. If a lessee, who has paid royalty at the schedule rates, produces within one year from the date of despatch from the mine, a shipper's certificate in the prescribed form showing the actual receipts for sales of mica under each dimension, he will be allowed to recover any royalty paid in excess. Where the removals are in the first instance covered by deposits, royalty at the schedule rates will be levied if the certificate above referred to is not submitted within the prescribed period of one year.

On application being made to the Board any house of business of assured standing in the City of Madras will be authorised to grant shipper's certificates.

As a tentative measure royalty will be calculated on the scale drawn up by the Board.

15. (*ii*) *Dead-rent.*—The lessee shall also pay for every year after the first year an annual dead-rent of one rupee per acre provided that no lessee shall pay both royalty and dead-rent in respect of the same lease but only such one of them as may be the greater in amount.

16. (*iii*) *Surface rent.*—The lessee shall also pay for all land which he may take up, use, or occupy for the purpose of the mine a surface rent equal to the land assessment in the case of classified and assessed lands and a uniform rate of one rupee per acre in the case of unassessed and poramboke lands.

17. *Size of Blocks.*—The length of a block shall not be allowed to exceed 4 times its breadth nor shall its extent be less than 3 acres or more than half a square mile. A mining lease may be granted over one or more such blocks, provided that the total area held under mining leases by the lessee, or by those joint in interest with him, does not exceed ten square miles.

18. *Surrender of leases and applications for larger areas.*—It will be open to the Collector to allow a lessee to give up his original lease and take out a new one embracing a larger area, provided the prescribed limits as regards time and area are not exceeded.

On receipt of an application for prospecting or for mining over a plot lying within 200 yards of an area already granted to a different individual under a mining lease, the Collector may, if he sees no objection, give this original lessee an opportunity of extending his lease area, if the rules permit, so as to include the whole or a portion of the extent newly applied for.

19. *Deposits.*—No mining lease shall be issued unless the lessee shall before the lease is granted deposit as security in respect of each lease such sum as the Collector may determine or give security to the like amount to the satisfaction of the Collector, the maximum deposit in any case being Rs. 500. Each lessee shall be responsible for filling up pits excavated by him unless the royalty paid in respect of each excavation exceeds Rs. 200.

20. The following will be insisted on as necessary conditions of a lease:—

(*i*) The lessee shall at his own expense erect and at all times maintain and keep in repair boundary marks and pillars according to the demarcation to be shown in a plan annexed to his lease.

(*ii*) The lessee shall not cut or injure any tree on the land covered by his lease without the permission of the Collector in writing, but it will be open to him to acquire any such trees at prices fixed by the Collector.

(*iii*) Neither the lessee nor any one claiming through or under him shall assign the lease, or transfer any right or interest thereunder, or underlet the whole or any portion of the premises comprised in such lease, without the previous consent in writing of the Local Government.

(*iv*) The lessee shall commence operations within two years from the date of the execution of the lease, and shall thereafter carry them on effectually in a proper, skilful and mining-like manner unless prevented by unavoidable cause.

(*v*) The lessee shall allow any officer authorised by the Local Government in that behalf to enter upon the premises comprised in the lease for the purpose of inspecting the same.

(*vi*) The lessee shall not without the consent in writing of the Collector despatch any consignment of mica from the mines unless it shall have been inspected and its removal authorized by a Government officer appointed for the purpose. The dates on which the inspection will be made will be notified to the lessee by the Collector,

but if the lessee desires to despatch the consignment on any other date, he shall give the Collector a fortnight's notice of such intention.

(*vii*) The lessee shall without delay send to the Collector a report of any accident which may occur at or in the said premises, and also the finding therein of any mineral not specified in the lease.

(*viii*) Should the royalty or rent reserved or made payable by the lease be not paid within two months next after the date fixed in the lease for the payment of the same, the Collector may enter upon the said premises and seize any minerals or movable property therein and may carry away or detain them until the rent or royalty due and all costs and expenses occasioned by the non-payment thereof shall be fully paid. If any rent or royalty remain at any time unpaid for six calendar months after the date on which it is due, the Collector may determine the lease and take possession of the premises comprised therein.

(*ix*) Any breach on the part of the lessee of the conditions of the lease renders the lease cancellable by Government.

21. In ordinary cases no mica operations will be permitted within a minimum distance of 70 yards of any irrigation source or channel. In the case of jungle streams, however, each case will be decided on its own merits. In any case 25 yards is however an irreducible minimum and that only on condition that no stone or earth is thrown into the course of the streams.

22. Should the applicant for a prospecting license or mining lease desire the Collector to prepare for him the sketch required by paragraph 2 (*b*) or the map required by paragraph 12 (*b*), the Collector may prepare the sketch or map required and recover the cost from the applicant at 4 annas per acre, or R3 per sketch or map, whichever is greater. All insufficient sketches will be rejected. The maximum sketch fee in respect of each mica mining block is R30. The sketch fee in the case of blocks exceeding 320 acres is calculated as follows:—

I. In excess of 320 acres but not exceeding 640 acres . .	R30+4 annas on every acre in excess of 320, the total being subject to a maximum of R60.

II. In excess of 640 acres but not exceeding 960 acres . . R60+4 annas on every acre in excess of 640, the total being subject to a maximum of R90, and so on

23. *Forms of licenses and leases.*—The forms of licenses, leases and accounts are prescribed by Government.

An account with respect to each mine shall be kept in the Collector's office and on the 1st March and September of each year an account in a specially prescribed form will be forwarded to every lessee from whose mine mica has been allowed to be removed during the preceding half-year on the security of deposits. If the amount of royalty shown to be due under that account is not paid within the 15th of the month, the Collector will be at liberty to proceed to realize the amount by the adjustment of the deposit.

Schedule showing the scale of values to be adopted for the purpose of calculating royalty leviable on every pound of mica removed from the premises of a mine:—

Class.		Coloured mica.			White mica.		
		R	*a.*	*p.*	*R*	*a.*	*p.*
I.	4 square inches and under . . .	0	2	0	0	3	0
II.	above 4 square inches and not more than 8 .	0	4	0	0	6	0
III.	do. 8 do. 16 .	0	10	0	1	0	0
IV.	do. 16 do. 32 .	1	8	0	3	0	0
V.	do. 32 do. 48 .	3	0	0	5	0	0
VI.	do. 48 do. 64 .	4	8	0	7	0	0
VII.	do. 64 do. 80 .	6	0	0	9	0	0
VIII.	do. 80 do. 96 .	7	8	0	11	0	0
IX.	do. 96 do. 112 .	9	0	0	13	0	0
	and so on.						

NOTE.—The size of plates shall be calculated for assessment according to the greatest rectangular area the slabs will yield.

REVISED RULES FOR THE GRANT OF PROSPECTING LICENSES AND MINING LEASES FOR MICA IN BENGAL.

[Approved in Bengal Government Notification No. 142 T. R., dated the 23rd April 1902.]

In these rules, Collector means the Revenue Officer in charge of the district.

Prospecting Licenses.

1. (1) A license to prospect for mica, called hereinafter a prospecting license, shall confer on the licensee the sole right, subject to the conditions contained in the license, to mine, quarry, bore, dig and search for, win, work, and carry away mica lying or being within, under, or throughout the land specified in the license.

(2) A prospecting license shall only be granted with respect to land in which the mica mines, or mica, is the property of the Government, and shall apply only to the area described in the license.

NOTE.—A prospecting license should be restricted to such area as is reasonably required for *bonâ fide* prospecting purposes. The Collector's powers in this respect are made subject to the control of the Local Government, and it is accordingly directed that in cases in which a prospecting license is applied for over an area exceeding half a square mile, a previous reference to the Local Government should be made by the Collector.

2. No prospecting license shall be granted except to a person approved by the Government, and such person shall, before the license is granted, deposit as security in respect of each license such sum not being less than R100, as the Collector may determine, or give security to the like amount to the satisfaction of the Collector. Subject to such deduction on account of compensation for surface damage or otherwise as the Collector may order, the amount of any deposit made under this rule, should the depositor afterwards become the lessee of any mica-mining lease, will be carried to his credit as part of the rents payable under his lease, and should he decline or fail to obtain any such lease as aforesaid, will be returned to him.

3. (1) Every application for a prospecting license for mica shall, unless the Local Government shall in any case otherwise direct, be made to the Collector of the district in which the land or some part of the land with respect to which the license is required, is situate.

(2) Every such application shall bear a court-fee stamp of the value of eight annas and contain the following particulars, namely :—

(*a*) the name, residence and profession of the applicant;

(*b*) a description as accurate as possible, and illustrated by a rough sketch, of the situation, boundaries, and area of the land with respect to which the license is required.

(3) Every application shall be accompanied by a certificate of approval signed by a Secretary to the Local Government.

NOTE.—In granting a certificate of approval the Local Government should satisfy itself that the person intends to carry out *boná fide* prospecting work and has sufficient means at his disposal.

4. On receipt of any such application the Collector shall, as soon as practicable, enquire whether the grant of the license applied for is inexpedient either on the ground that the land described in the application is required for a public purpose, or otherwise.

5. (1) Should the Collector be of opinion that it is not expedient to grant the license, or should he find that the licensee has not been approved by the Local Government, he shall refuse to grant the license, and shall forthwith report the matter through the proper channel to the Local Government, which may pass such orders as it may think fit.

(2) Subject to the control of the Local Government, the Collector, if he finds that there is no objection to the grant of the license applied for, and if the applicant has been approved by the Local Government, may grant to the applicant a license in such form as may be prescribed, and shall report the matter to the Local Government or such other authority as the Local Government may direct.

NOTE.– Exploring and prospecting licenses are chargeable for stamp duty as agreements, *i.e.*, they must pay a stamp duty of 8 annas under article 5 (*b*) of Schedule I of the Indian Stamp Act, II of 1899. *Vide* Government of India's Circular in Revenue and Agricultural Department's No. 1677S. R., dated 10th April 1902.

6. A register of applications for prospecting licenses shall be kept in English in the Collector's office, specifying—

(1) Number of application.
(2) Date.
(3) Name of applicant.
(4) Residence of applicant.
(5) Situation of the land.
(6) Boundaries.
(7) Estimated area.
(8) Date of certificate of approval of applicant by the Local Government.
(9) Date of license.
(10) Rent and royalty payable.
(11) Period for which granted.

7. Every prospecting license shall contain such conditions as may in any particular case seem necessary, and shall in all cases contain the following conditions :—

(i) The term for which the license shall be granted shall be one year or such shorter term as the applicant may desire. The license may be renewed by the Collector for a further term not exceeding two years, whenever he is satisfied that the licensee has been prevented from completing his search of the land by any cause other than his own default.

(ii) A moderate rent not exceeding one rupee per acre shall be paid for the land covered by the license.

(iii) The licensee shall pay a royalty at 5 per cent. of the value of the mica won and carried away over and above such quantity as the Collector, subject to the orders of the Local Government, may allow to be taken free for purpose of experiment.

(iv) No land in the occupation of any person shall be entered upon without the consent of the occupier, and no trees, standing crops, or other private property shall be cut or in any way injured without the consent of the owner thereof.

(v) The licensee shall make and pay reasonable satisfaction and compensation for all injury which may be done by him in exercise of the powers granted by the license, and shall indemnify the Government against all such claims which may be made by third parties in respect of any such damage or injury.

(vi) The licensee shall not cut or injure any tree on unoccupied and unreserved land without the permisssion of the Collector in writing.

(vii) Such license cannot be assigned nor can any right or interest thereunder be transferred without the consent of the Local Government.

NOTE.—The Local Government will, as a general rule, withhold sanction if no prospecting work has been done by the licensee, and there is reason to believe that he obtained the license solely with a view to immediately selling it out and out at a profit. On the other hand, sanction may with propriety be given if the licensee requires further resources, or proposes to associate other persons, by way of a partnership, Syndicate, or Joint Stock Company, with himself in the undertaking, if the assignment or transfer appears to be a *bonâ fide* arrangement, and if the transferee is a person or Company whom the Government would be willing to approve as a prospector. Hitherto the practice has been to unfavourably regard or absolutely prohibit transfers of prospecting licenses, on the ground that ordinarily there was nothing assured to transfer, that the transfer was proposed with the sole object of making money out of the public, and that, if the licensee was unable to work his concession, his proper course was to resign it. Under the new rules, the attitude of the Government will be less strict.

(viii) In case of any breach on the part of the licensee of any of the five last preceding clauses, the Collector may summarily revoke the license, and hereupon all rights conferred thereby or enjoyed thereunder shall cease.

(ix) The licensee shall, within six months next after the determination of the license or the date of the abandonment of the undertaking, whichever shall first occur, securely plug any bores and fill up or fence any holes or excavations that he may have made in the land to such extent as the Collector may require, and shall to the like extent restore the surface of the land and all buildings thereon which he may have damaged in the course of prospecting: Provided that this clause shall not apply to any land held under a mining lease.

(x) Should any question of dispute arise regarding the license, or any matter or thing connected therewith, or the powers of the licensee thereunder or the amount or payment of the rent or royalty made payable there by, the matter in difference shall be decided by the Local Government, whose decision shall be final.

Mining Leases.

8. On or before the determination of his prospecting license, the licensee shall have a right, subject to the rule hereinafter contained, and provided that the Local Government is satisfied that the prospecting has been of a *boná fide* character, to a mining lease in accordance with the terms contained in the rules for such leases.

Such lease may include an area not exceeding half a square mile, whether comprising the whole or part only of the area for which the prospecting license was granted.

9. (1) Every application for the grant of a mica-mining lease shall be presented to the Collector in whose district the land or some part of the land with respect to which the lease is applied for is situate. The Collector shall forward the application through the proper channel to the Local Government. The Local Government may by general or special order require a deposit of money not exceeding R500 to be made by the applicant in any case or class of cases before the application is taken into consideration.

(2) No mica-mining lease shall be granted otherwise than with respect to land in which the mine or mica is the property of Government or to any persons but approved capitalists who are willing to conduct operations on approved methods.

10. Every application for a mica-mining lease shall bear a court-fee stamp of the value of eight annas and contain—

(*a*) the name, residence, and profession of the applicant, and

(*b*) a map of the area over which the proposed lease is to extend.

11. On receipt of any such application the Local Government may, if the applicant is entitled to a lease under rule 8, or if it considers that the applicant should be granted a mining lease, grant the same in accordance with these rules over such one or more blocks, each not exceeding half a square mile in area, as the Local Government may think fit:

Provided that no mica-mining lease shall be granted by a Local Government under these rules so as to cause the total area held under mining leases by the lessee, or by those joint in interest with him, to exceed ten square miles.

No such lease shall be executed until it has been approved by the Legal Remembrancer or other legal adviser, if any, appointed for the Province.

NOTE.—The Local Government is empowered to grant to an applicant more than one block of land, if it considers this expedient. But the right of a prospector in respect of a mining lease is limited to one block. The granting of more than one block to him is entirely in the discretion of the Local Government. The number of blocks which may properly be granted under any one lease is a matter of importance and will vary with the resources at the command of the applicant, the area of mineralised land in the locality at the disposal of the Government, and the possibility of other capitalists being likely to engage in the same industry.

12. Without the previous sanction of the Governor-General in Council, the extent of each lot or block of land covered by a mica-mining lease shall not exceed half a square mile, and where the land follows the direction of a band or belt of mica, the length of the lot shall not exceed four miles.

13. The term for which a mica-mining lease shall be granted must not exceed thirty years, and no covenant for renewal shall be inserted in the lease without the previous sanction of the Governor-General in Council.

NOTE.—The Government of India would not be prepared to sanction a renewal clause in leases for purely speculative undertakings. On the other hand, they would be disposed to view with favour a proposal for a covenant for renewal where the existence of the mineral is ascertained beyond doubt where the enterprise is a substantial one, and where a large expenditure of capital is essential to the prosecution of the undertaking.

14. Every such lease shall contain such conditions and stipulations as the Government of Bengal may in each case consider necessary, but shall in every case contain the following conditions:—

(i) The lessee shall, during the currency of his lease, pay either a royalty of 5 per cent. *ad valorem* on all mica removed or

won from his mine, or a yearly dead-rent at Re. 1 per acre, whichever may be the greater in amount. The royalty will be assessed on the sale value of the mica as shown in the books of the lessee, or as estimated by Government if, for any sufficient reason, the entries in the lessee's books be not accepted, after deducting therefrom the amount paid for freight and transit from the mine. The dead-rent shall be payable in equal half-yearly instalments, the first payment to be made on such date as may be agreed to under the terms of the lease.

(ii) The lessee shall have the power to relinquish his grant at any time during the currency of his lease on good and satisfactory reasons being shown to the Collector, and after paying in full the dead-rent for the year in which the grant is relinquished and for the next year. As an alternative a lessee may surrender his lease subject to the conditions specified in the rule appended to Government of India Circular in Revenue and Agricultural Department, No. 19—1·4, dated 10th April 1902, *i.e.*, by giving not less than 12 calendar months' notice in writing, and upon expiration of such notice, paying all rents, dues, royalty, compensation for damage, and other moneys which may then be due.

(iii) The lessee shall at his own expense erect and at all times maintain and keep in repair boundary marks and pillars according to the demarcations to be shown in a plan annexed to his lease.

(iv) Where the area leased lies within a Reserved or Protected Forest, the lessee shall at his own cost clear a line 30 feet in width all round the surface leased to him (but included in the leased area) of all trees, wood, grass, leaves, sheds, huts, and inflammable material generally. He shall maintain this line clear as above every year during the months of February, March, April, May, and June.

(v) No lessee of any block leased under these rules for mining purposes shall divert any road, path or bye-way on the block leased, or any water-course beyond the limits of the block leased to him, and all water running waste on such block shall be returned to its natural channel within the limits of the same block.

(vi) The lessee shall make and pay reasonable satisfaction and compensation for all injury which may be done by him in exercise of the powers granted by the lease, and shall indemnify the Government against all claims which may be made by third parties in respect of any such injury.

(vii) The lessee shall not cut or injure any tree reserved in the lease. Where the area leased lies within a Reserved or Protected Forest, the lessee shall at once give to the Forest Officer in charge of the forest a full description of any timber or tree destroyed or injured by him.

(viii) Neither the lessee nor any person claiming through or under him shall assign the lease or underlet the whole or any portion of the premises comprised in such lease, without the previous consent in writing of the Local Government.

NOTE.—Before granting sanction to the transfer or assignment of a mining lease as required by the rules, the Government should satisfy itself that the proposed transfer is a *bonâ fide* transaction, that the transferee is a person or Company of substance, and can be relied on to fulfil, in relation to the Government, the conditions and stipulations of the lease. It is not, however, intended that the Government should undertake responsibility towards the public for the accuracy of any prospectus which the transferees may intend to issue, or should closely examine the details for the proposed transfer or of the arrangements contemplated after it has taken effect. If in any particular case the Local Government feels a difficulty as to how its discretion should be exercised, a reference should be made to the Government of India.

(ix) The lessee shall commence operations within two years from the date of the execution of the lease, and shall thereafter carry them on effectually in a proper, skilful, and mining-like manner unless prevented by unavoidable cause.

(x) The lessee shall keep correct accounts showing the quantity and particulars of all mica obtained from the mine and the number of persons employed therein, and also complete plans of the mine, and shall allow any officer authorised by the Local Government in that behalf at any time to examine such accounts and plans, and shall furnish that Government with such information and returns in respect of the aforesaid matters as it may prescribe.* He shall also keep his accounts of the mica obtained from Government mines separate from those relating to mines in private lands if he has any such mines.

(xi) The lessee shall allow any officer authorised by the Local Government in that behalf to enter upon the premises comprised in the lease for the purpose of inspecting the same.

(xii) The lessee shall without delay send to the Collector a report of any accident which may occur at or in the said premises, and also the finding therein of any other mineral than mica.

(xiii) Should the royalty or rent reserved or made payable by the lease be not paid within two months next after the date

fixed in the lease for the payment of the same, the Local Government may enter upon the said premises and distrain all or any of the minerals or moveable property therein, and may carry away or detain them until the rent or royalty due and all costs and expenses occasioned by the non-payment thereof shall be fully paid; and if any royalty or rent remain at any time unpaid for six calander months after the date on which it is due, the Local Government may determine the lease and take possession of the premises comprised therein.

(xiv) In case of any breach on the part of the lessee of any covenant contained in the lease, the Local Government may determine the lease and take possession of the said premises.

(xv) At the end or sooner determination of the lease, the lessee shall deliver up the said premises and all mines (if any) dug therein in a proper and workman-like state, save in respect of any working as to which the Local Government may have sanctioned abandonment.

(xvi) Should any question or dispute arise regarding the lease or any matter or thing connected with the mines and mica leased or the working or non-working thereof, or the amount or payment of the royalty or rent reserved or made payable by the lease, the matter in difference shall be decided by the Local Government, whose decision thereon shall be final.

* NOTE.—All information and returns obtained or furnished under this clause shall be treated as strictly confidential.

15. (1) All operations conducted under the authority of these rules within a Reserved Forest shall be subject to such conditions as the Local Government may by general or special order from time to time prescribe.

(2) It shall be a condition of every license granted under these rules that, before the commencement of prospecting within a Reserved Forest, notice shall be given to the District Forest Officer of the intention to commence operations, and that the operations shall be conducted subject to any conditions regarding the use of fire that he may prescribe: Provided that the licensee shall not enter on the land covered by the license, nor commence operations, without the written permission of the Collector.

(3) Every mining lease which includes any portion of a Reserved Forest shall, if it authorises the lessee to fell timber for mining purposes, specify the area within which or the quantity up to which, and the terms and conditions upon which, he may exercise that authority.

16. Should the applicant for a prospecting license or mining lease desire the Collector to prepare for him the sketch required by rule 3 (2) (*b*) or the map required by rule 10 (*b*), or should the sketch or map presented by the applicant be insufficient, the Collector may prepare the sketch or map required, and may, if he so order, recover the cost from the applicant at a rate not exceeding 4 annas per acre. If the Government of Bengal has prepared a map of a tract of country specially for the convenience of intending applicants for licenses and leases under these rules, and if any applicant makes use of such map for the sketch or map aforesaid, it will be open to that Government to recover as above such share of the cost of preparing the map as it may consider to be equitably due from such applicant.

17. If license or lease is not executed within six months after lease has been granted for it, the right of the applicant to such license or lease shall be held to have lapsed, unless the Local Government, for special reasons, consents to grant the same, notwithstanding the delay.

VII.—PUBLISHED LITERATURE.

General.

Ball, V.—Manual of the Geology of India, Part III: Economic Geology, pp. 524—528 (1881).

Mallet, F. R.—Manual of the Geology of India, Part IV: Mineralogy, pp. 96—99 (1887).

Tagore, Raja Sir Sourindro Mohan.—Abhra, or a few notes on talc, compiled and translated into English from various Sanskrit works (1899).

Siföcz, L.—"Kaliglimmer aus Ostindien." *Tschermak's min. und petr. Mittheil.*, 1873, p. 31.

Bengal.

Breton, Dr. P.—"Description of the animals and reptiles met with in the districts of Ramgur, Surgoojah and Sambhulpore, and of the principal mineral productions of these provinces." *Trans. Med. and Phys. Soc. Calcutta*, Vol. II, p. 261 (1826).

McClelland, Dr. J.—Report on the Geological Survey of India, for the season of 1848-49, pp. 20 and 21 (1849).

Mallet, F. R.—"Geological notes on part of Northern Hazaribagh." *Rec. Geol. Surv. Ind.*, Vol. VII, pp. 32—44 (1874).

Sherwill, Capt. W. S.—"A sketch of the Behar mica mines." *Journ. As. Soc. Beng.*, Vol. XX, pp. 295—298 (1851).

Blau, S.—"Kaliglimmer aus Bengalen." *Tschermak's min. und petr. Mittheil.*, 1873, p. 32.

Coggan, W.—"Mica Mining in Bengal." *Ind. and East. Engineer*, New Ser., Vol. I, p. 121 (1897).

Waddell, L. A.—Among the Himalayas, p. 408 (1898).

Mervyn Smith, A.—Report on the Bendee and Jhirkee Mica Properties in the Hazaribagh District, Chota Nagpur, Bengal, 1898.

Mervyn Smith, A.—"Mica Mining in Bengal." *Trans. Inst. Mining and Metallurgy*, Feb. 1899.

BOMBAY.

Fulljames, Major G.—"Geological and statistical notes on portions of the Rewa Kanta districts." *Sel. Rec. Bomb. Govt.*, No. XXIII, p. 101 (1852).

CENTRAL PROVINCES.

Grant, C.—Gazetteer of Central Provinces, p. 18 (1870).

MADRAS.

Carmichael, D. F.—District Manual, Vizagapatam, p. 155 (1869).

Brough Smyth, R.—Report on the gold mines of the south-eastern portion of the Wynaad and Carcoor ghat, pp. 6 and 37 (1880).

King, W., and Middlemiss, C. S.—Provisional Index of the local distribution of important minerals. Additions for the Madras Presidency up to July 1896, pp. 15 and 16.

Warth, H.—"The mica mines in the Nellore district." *Proc. Board of Revenue (Madras)*, No. 279 of 1892.

Thompson, R. W.—"Mica mining in the District of Nellore, India." *Journ. Soc. Arts.*, Vol. XLVI, pp. 671–673 (1898).

MYSORE.

Rice, L.—Gazetteer of Mysore, p. 19 (1900).

PUNJAB.

Mallet, F. R.—"On the gypsum of Spiti, with a list of the minerals collected in the Himalayas, 1864." *Mem. Geol. Surv. Ind.*, Vol. V, p. 169 (1864).

Powell, Baden H.—Hand-book of the Economic Products of the Punjab, Vol. I, p. 42 (1868).

Channing, F. C.—Settlement report, Gurgaon district, p. 41 (1882).

RAJPUTANA.

Irvine, R. H.—Some account of the general and medical topography of Ajmeer, p. 165 (1841).

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Survey of India Offices, Calcutta, January, 1901

MICA CUTTERS AT WORK,
BIRAPAVOL NELLORE DISTRICT
Photographed by T. L. Walker

T H Holland

Photogravure

Survey of In: cut

FOLDED PEGMATITE-VEINS IN SCHIST,

SAKRI NADI, ABOVE BAGIANT, HAZARIBAGH DISTRICT

Photographed by H H Hayden.

Photogravure Survey of India Offices, Calcutta, February 1901

MASS OF QUARTZ IN A MICA QUARRY,
INIKURTI, NELLORE DISTRICT

Photographed by T H Holland

T H Holland

Photogravure

Survey of India Offices, Calcutta, January 1901

ENTRANCE TO MICA MINE

KODERMA FOREST HAZARIBAGH DISTRICT

Photographed by T H Holland

GEOLOGICAL SURVEY OF INDIA

H. Holland

Memoirs, Vol. XXXIV Pl.

Photogravure

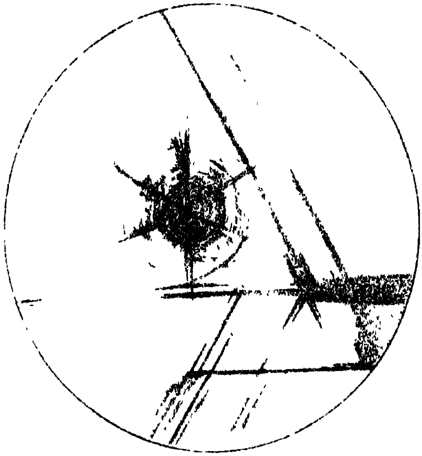
Survey of India Offices, Calcutta, January 19

BOOKS OF MICA EXPOSED IN QUARRY

INIKURTI, NELLORE DISTRICT

GEOLOGICAL SURVEY OF INDIA

T. H. Holland. Memoirs, Vol XXXIV, Pt 2, Pl. VI



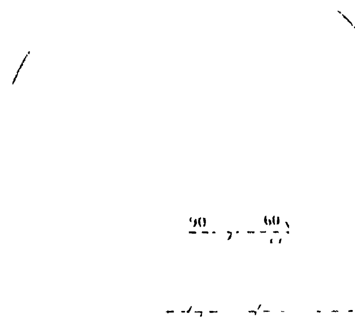


Fig. 1 a

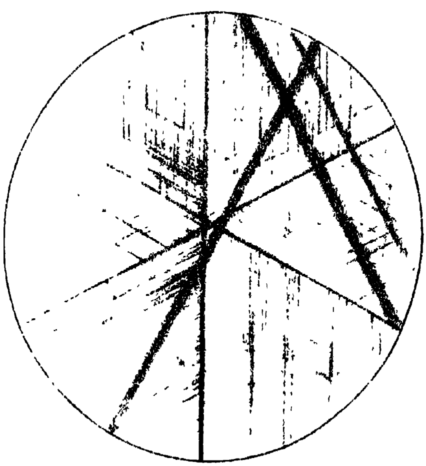


Fig. 2

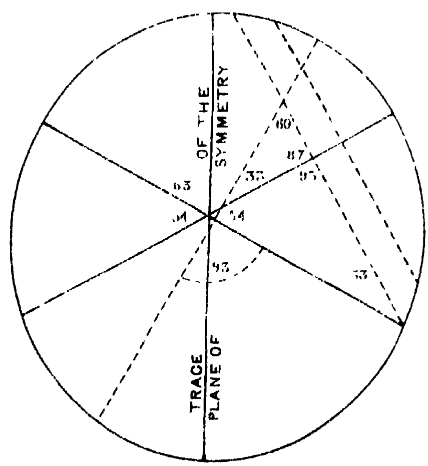


Fig. 2 a

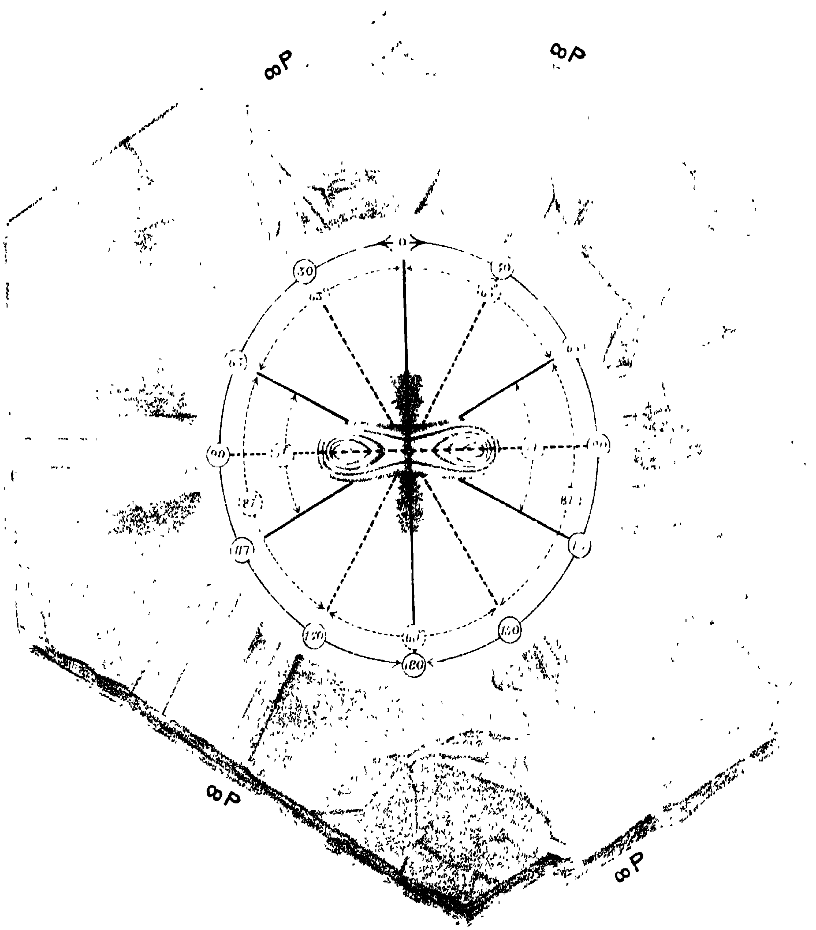
From Photographs by T. H. Holland

Lith., Geol. Surv. of India Office

PERCUSSION AND PRESSURE - FIGURES IN MUSCOVITE.

Figures 1 and 2, from microphotographs magnified by 20 diameters.

Figures 1a and 2a, diagrams showing the angular relations of the cracks.



From a Drawing by T. H. Holland. Lith., Geol. Surv. of India Office.

CRYSTAL OF MUSCOVITE,

showing the symmetrical disposition of the optic axial plane, percussion-figure and natural pressure-figure.

Turpunpandla, Nellore district.

(Natural Size)

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